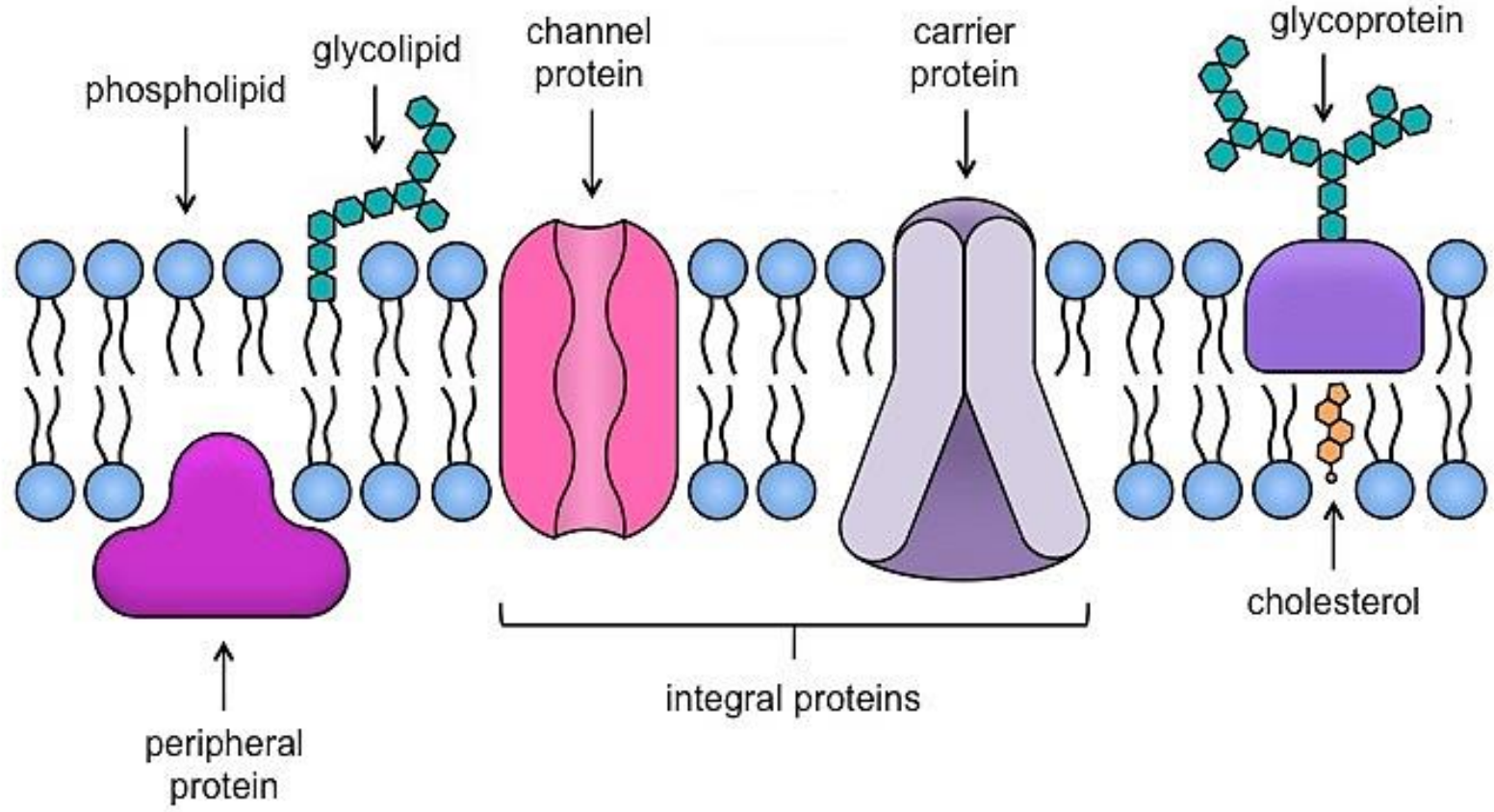
Cambridge Assessment International Education

AS Level
Chapter 4

Cell Membranes and Transport



Chapter Outline

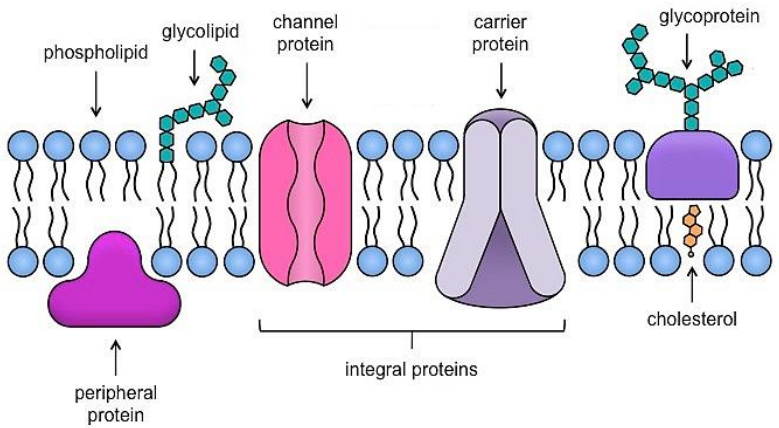
Part 1: Cell Membrane Structure and Function

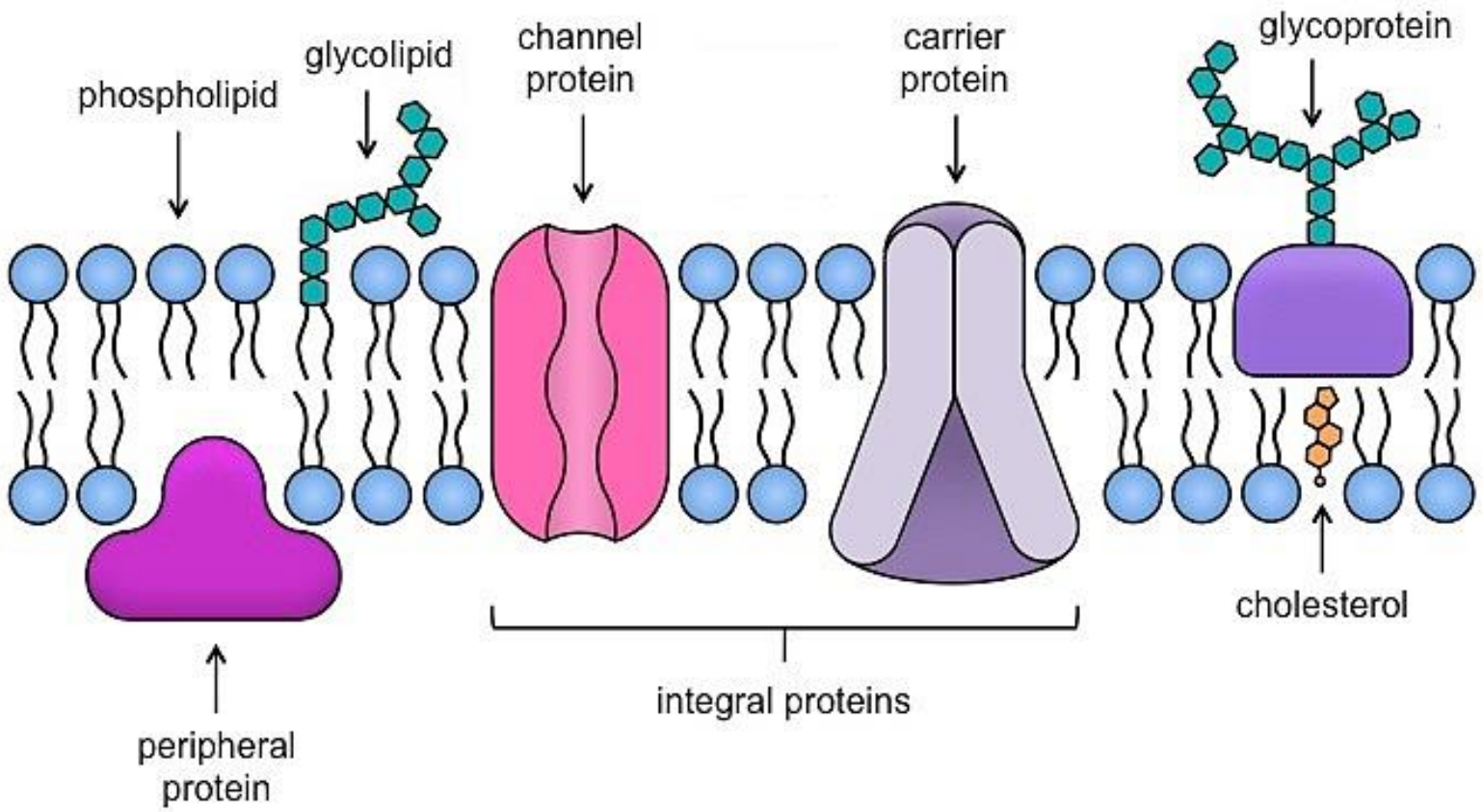
- Fluid mosaic model
- Roles of:
  - Phospholipids
  - Cholesterol
  - Proteins
  - Glycolipids
  - Glycoprotein

Part 2: Cell signalling

Part 3: Transport Across Membrane

1. Diffusion
2. Facilitated diffusion
3. Osmosis
4. Active transport
5. Endocytosis and exocytosis

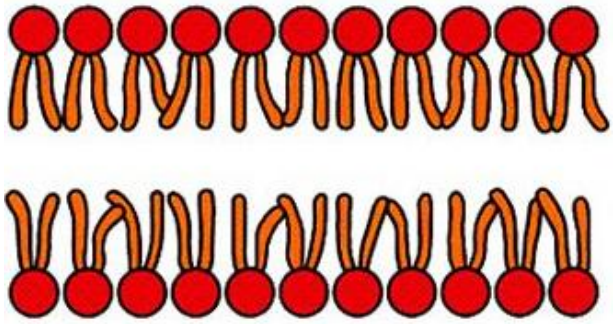




CELL MEMBRANE STRUCTURE AND FUNCTION

Cell Surface Membrane

- Aka plasma membrane
- **~7nm thick**



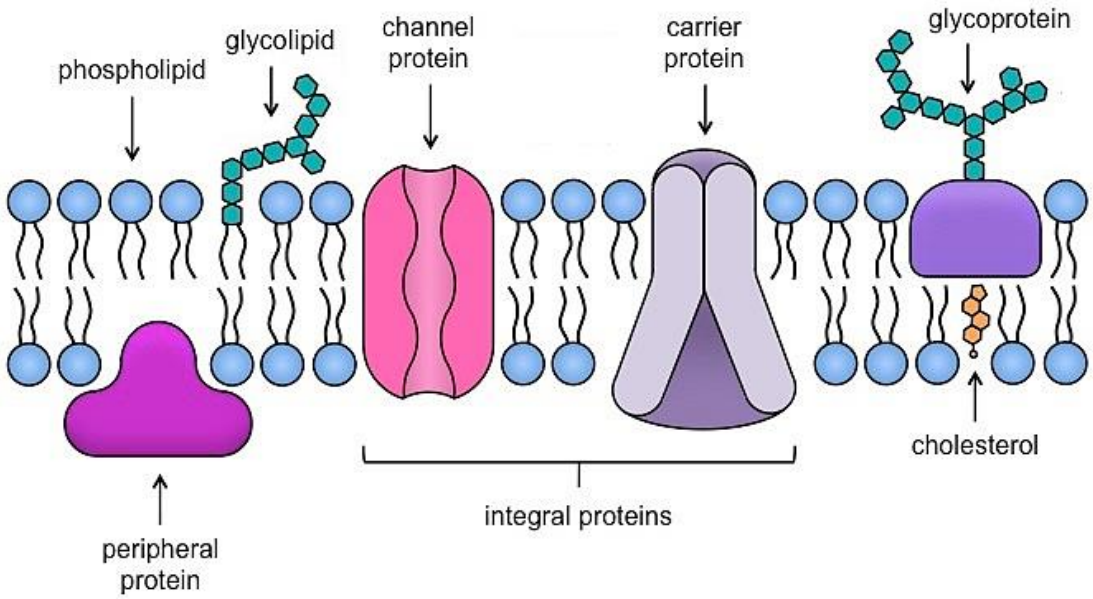
Roles:

1. **Controls movement of substances into and out of the cell**
   E.g. Nutrients, waste products

2. **Semi-permeable**
   - **Barrier** to **water-soluble** substances
   - **Allow** passage of **lipid-soluble** substances

Plasma Membrane

And many more roles due to the many components found at the membrane:

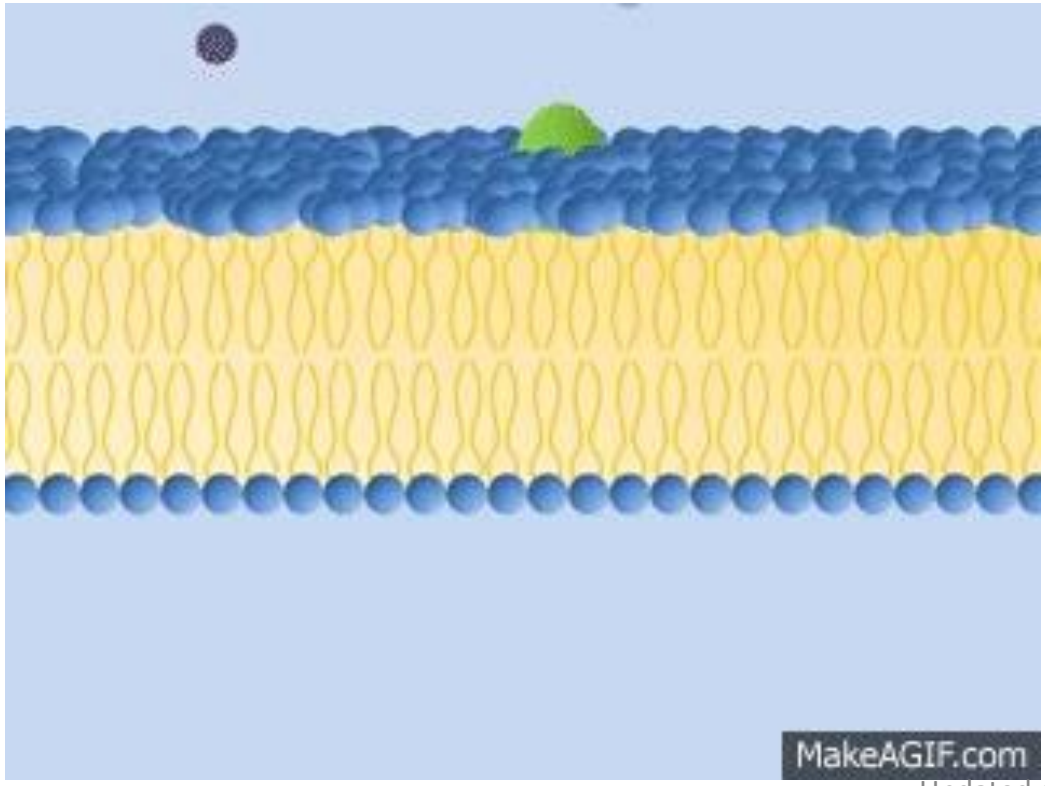


3. Cell signaling
4. Cell recognition
5. Cell-to-cell adhesion
6. Site for enzymes to catalyse reactions
7. Anchoring for the cytoskeleton
8. Form H bonds with water for stability

Fluid Mosaic Model

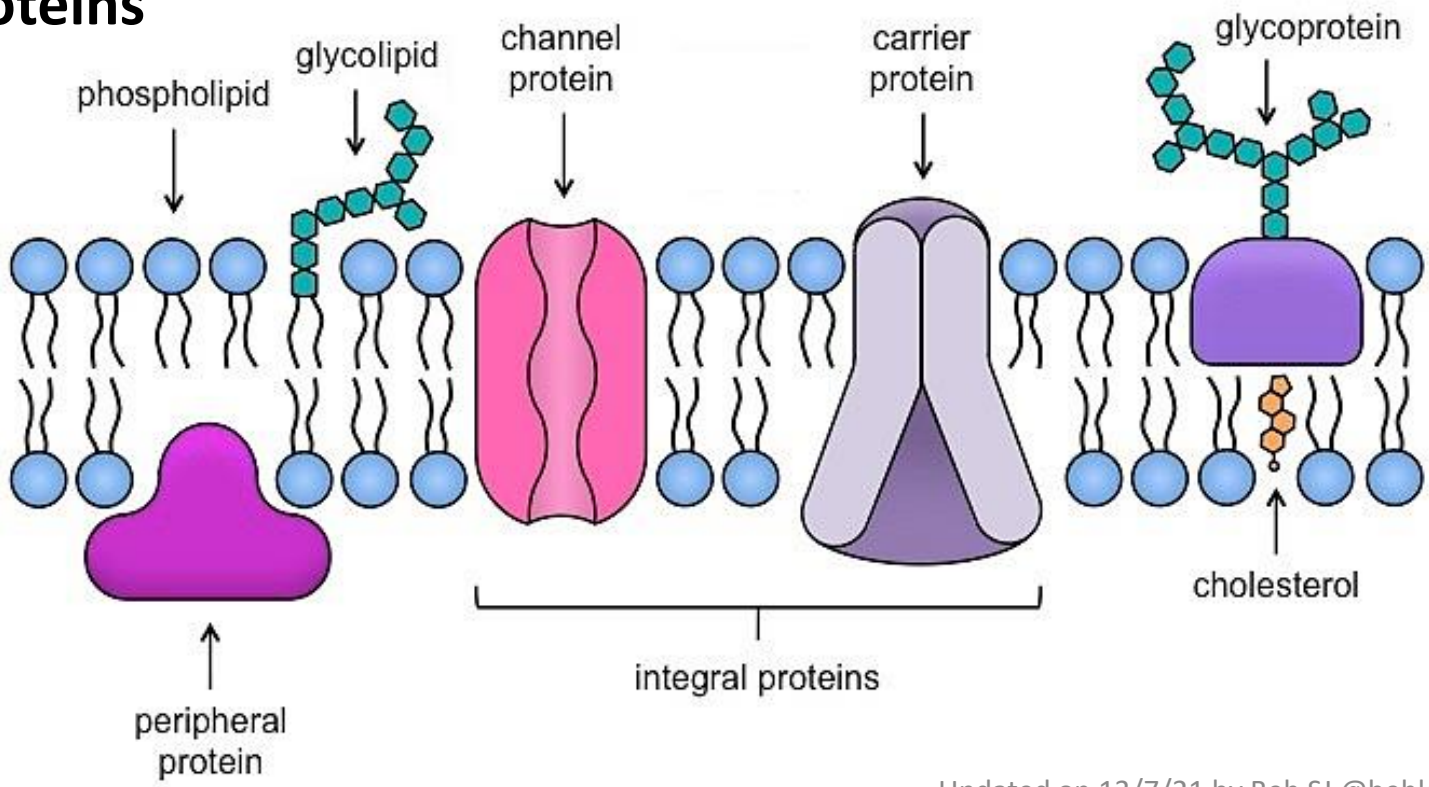
- **Fluid** – **phospholipids and protein molecules are able to move about** and diffuse sideways within its monolayer

- **Mosaic** – **proteins interspersed / scattered** within membrane



Components of the Plasma Membrane

1. **Phospholipids**
2. **Cholesterol**
3. **Proteins**
4. **Glycolipids**
5. **Glycoproteins**



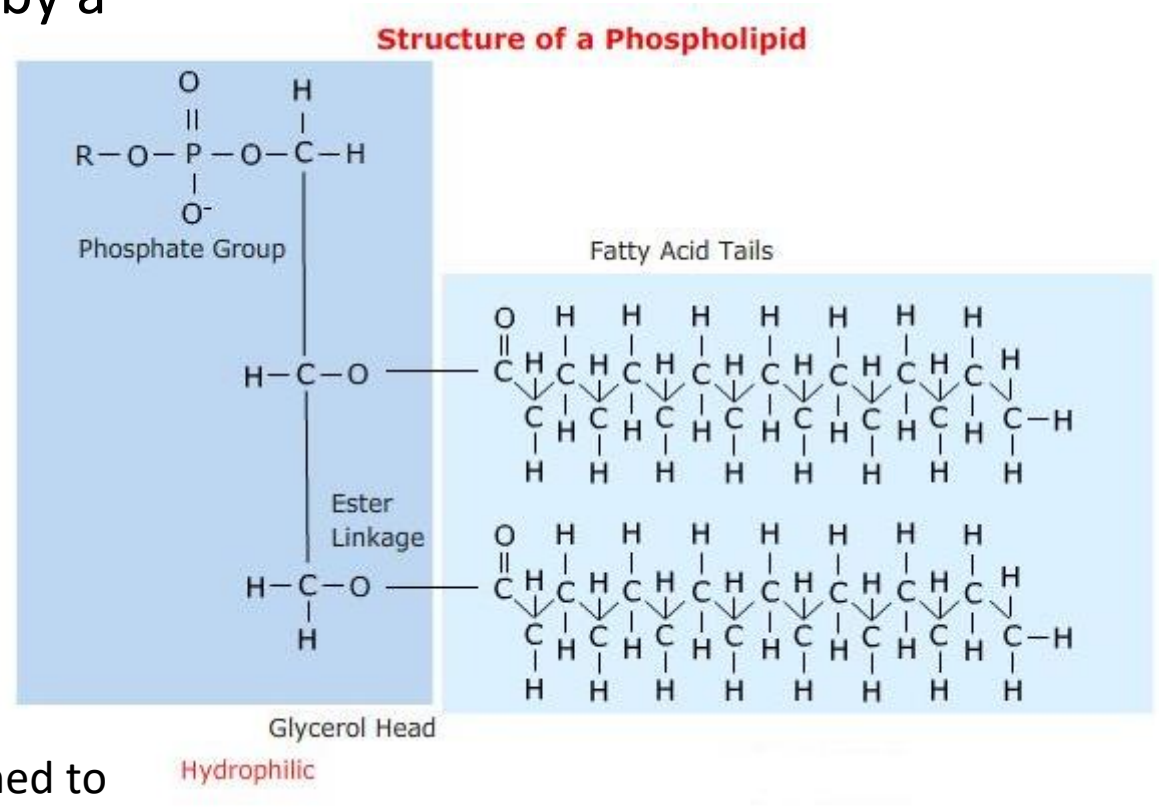
1. Phospholipids

Chap 2 Recap

- 1 fatty acid chain in triglyceride is replaced by a phosphate group

Composed of:

- **1 glycerol**
- **2 fatty acids**
- **1 phosphate gp** (PO_4^-)



- May also have other gps attached to phosphate gp (represented by R)

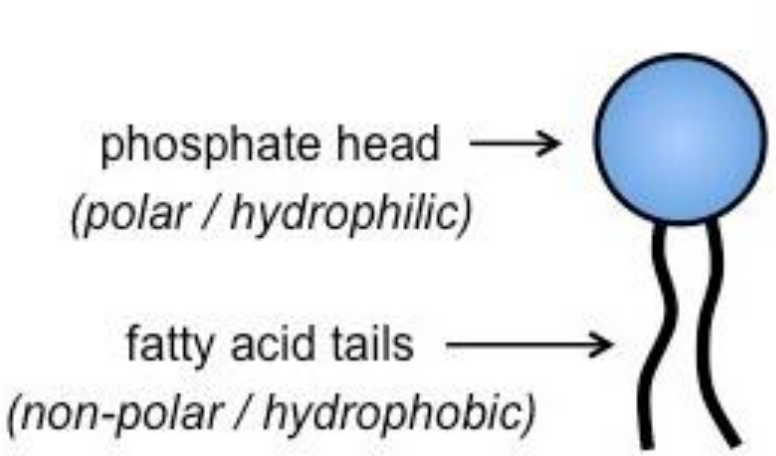
1. Phospholipids

Chap 2 Recap

a) **Hydrophilic head**

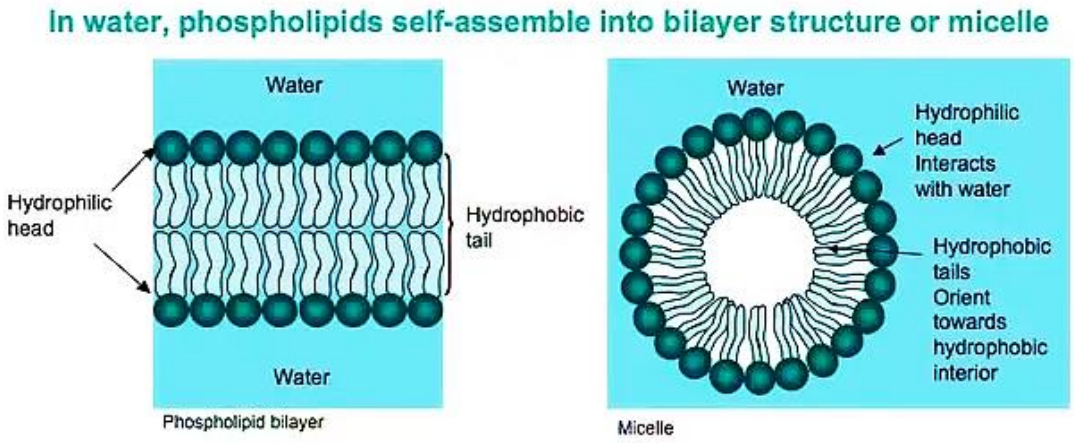
- **Phosphate group**
- Charged, polar
- Forms **H bonds** with water

→ ***Role:*** **Stabilise membrane**

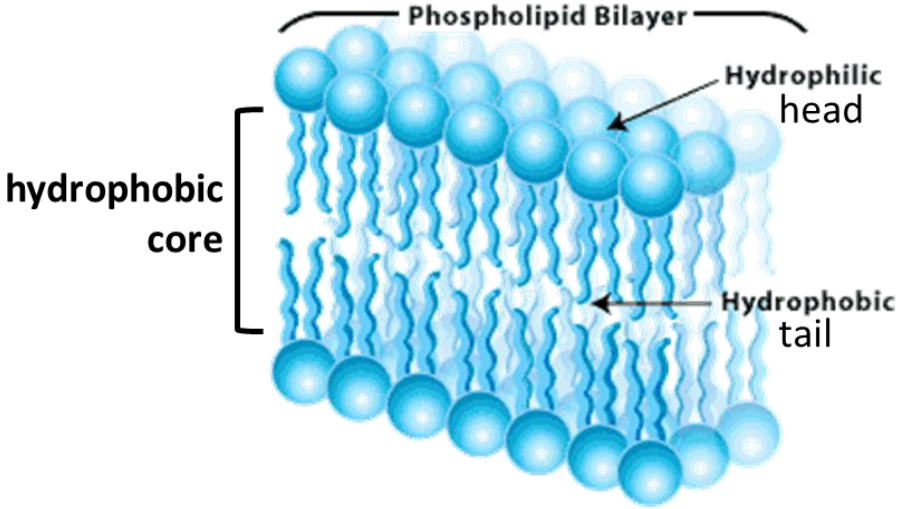


b) **Hydrophobic tails**

- **Fatty acid residues**
- Hydrocarbon chains are insoluble and non-polar
- Repels water



1. Phospholipids



b) **Hydrophobic tails**

- Point inwards facing each other

→ Form hydrophobic core

Roles:

Barrier to **water-soluble** substances

Allow passage to **lipid-soluble** substances

Only **lipid-soluble, small, uncharged molecules** can diffuse through the phospholipid bilayer

- Also! Fatty acids help **maintain fluidity** of membrane

What affects membrane fluidity?

1. Temperature

- **Higher temperature, higher kinetic energy, more fluid**

2. Ratio of unsaturated to saturated fatty acids

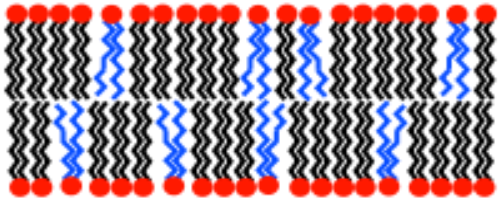
- **More unsaturated FA, higher unsat:sat ratio, more fluid**

→ Unsaturated FA has C=C which cause **kinks**

→ Phospholipids more **loosely arranged**

- **More saturated FA, lower unsat:sat ratio, less fluid**

→ No kinks, **more area for phospholipids to interact**



Mixed saturated and unsaturated

What affects membrane fluidity?

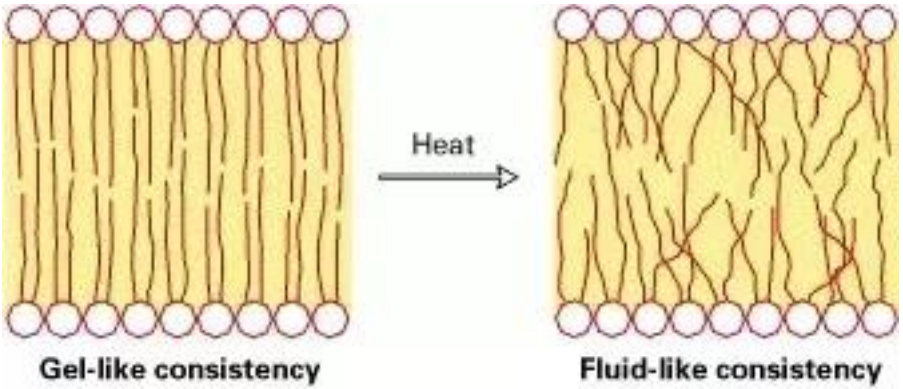
3. Length of phospholipid tails

- **The longer the tails, less fluid**

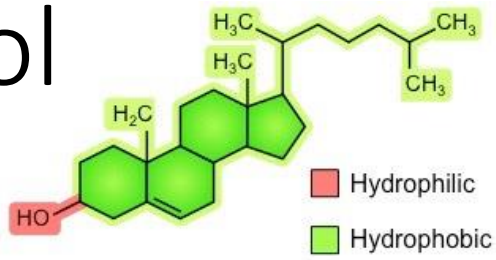
→ **More surface area** for interaction between tails

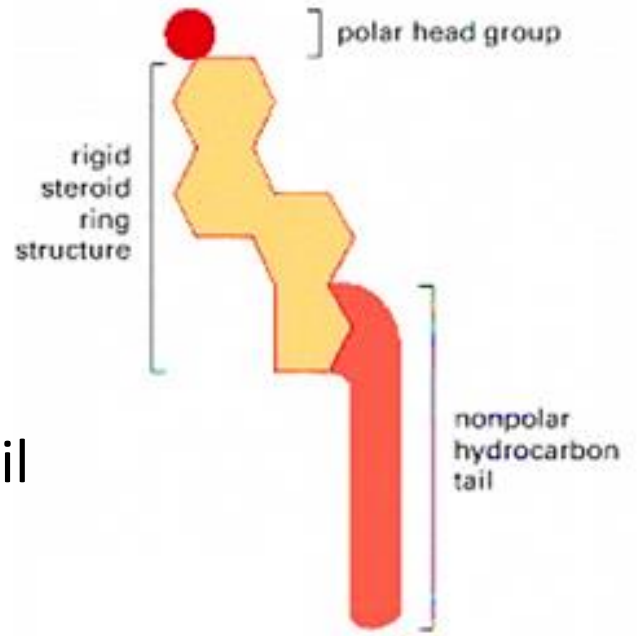
4. Cholesterol!

The cell can **maintain fluidity** during higher / lower temperatures by changing the ratio of unsat:sat, length of tails, and adding cholesterol!



2. Cholesterol

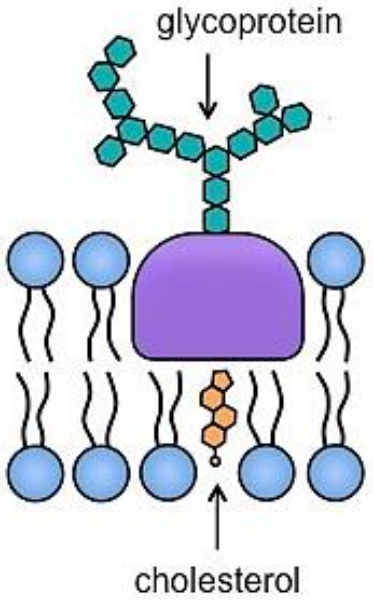




- Small molecule
- Has hydrophilic head and hydrophobic tail
- Fit between the phospholipid molecules
- Not found in prokaryotes' cell membrane

Roles:

1) **Regulates fluidity** of membrane
2) **Stabilises the membrane**
   esp the hydrophobic layer
3) **Block passage of very small ions**
   through membrane

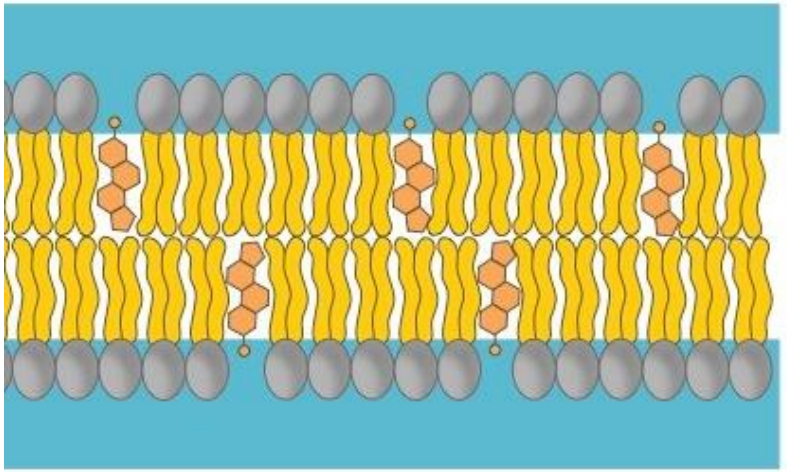


How Cholesterol Regulates Membrane's Fluidity

a) At lower temperatures, less fluid

- Cholesterol **increases fluidity** / decrease rigidity

→ **Prevent close packing** of the phospholipid tails



b) At higher temperatures, more fluid

- Cholesterol **decreases fluidity**

→ **Reduce mobility of phospholipids**

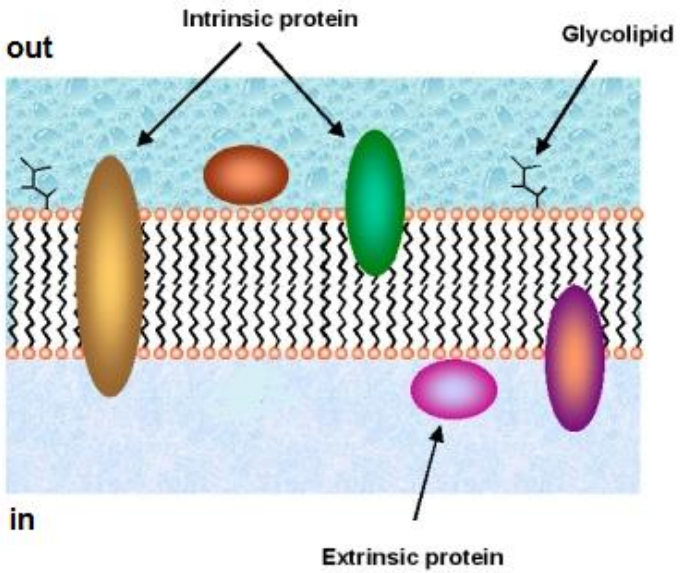
Overall, it ***stabilizes the membrane***

3. Membrane Proteins

Types based on their position in the membrane:

Extrinsic / peripheral proteins

- Inner or outer surface of the membrane



Intrinsic / integral proteins

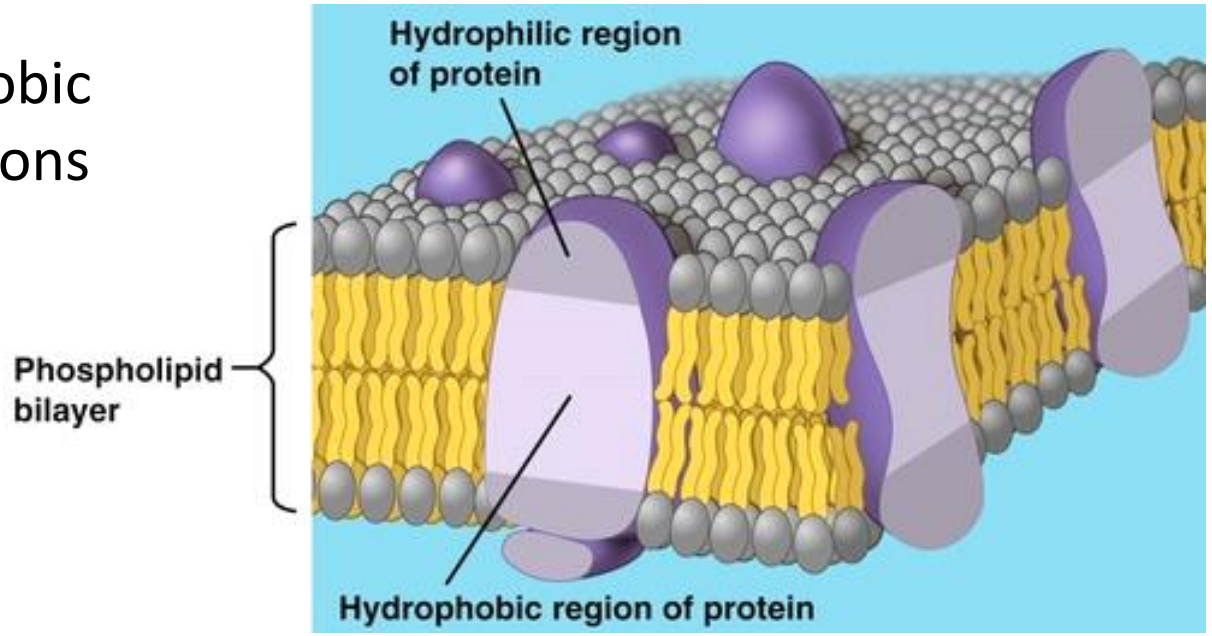
- Extend into hydrophobic core
- Maybe mobile or fixed (attached to structures)
- Some are **transmembrane proteins**

→ Span across the membrane

→ E.g. **transport proteins**

Structure of Intrinsic Proteins

- Have both hydrophobic and hydrophilic regions



- **Hydrophobic regions**

→ interacts with **hydrophobic core / fatty acids tails** of phospholipids

- **Hydrophilic regions**

→ Extend into **aqueous external environment** inside/ outside the cell

3. Membrane Proteins

Roles:

1) Transport proteins

✓ Passage for **ions / charged / polar / larger molecules** through membrane

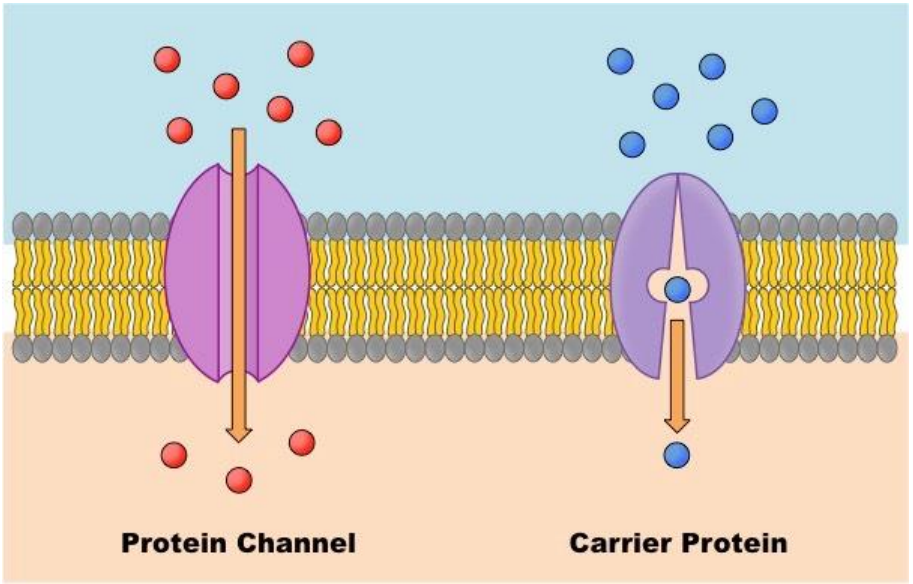
Two types:

- **Channel proteins**

→ For facilitated diffusion

- **Carrier proteins**

→ For facilitated diffusion / active transport



3. Membrane Proteins

Channel proteins:

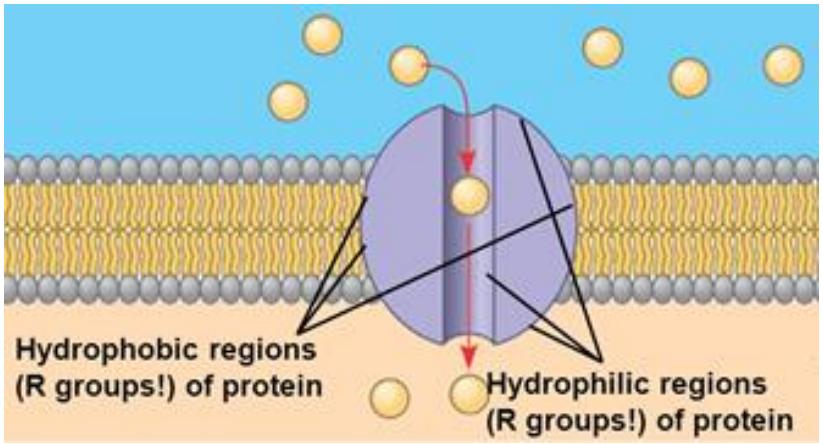
- **Highly specific**
- Channel /pore is **water-filled**

→ **Hydrophilic R-groups on amino acids face inwards towards channel**

→ E.g. **aquaporins** = channel protein for water

- Can be gated / can open and close

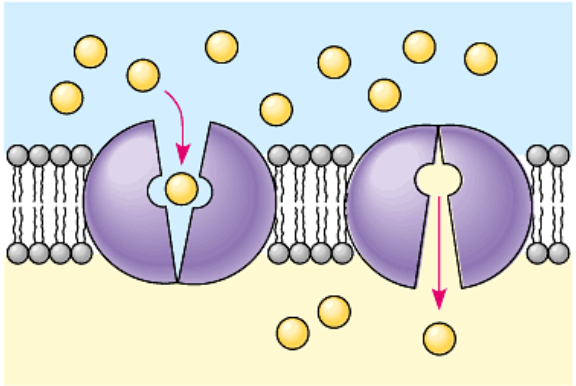
→ E.g. voltage-gated or ligand-gated



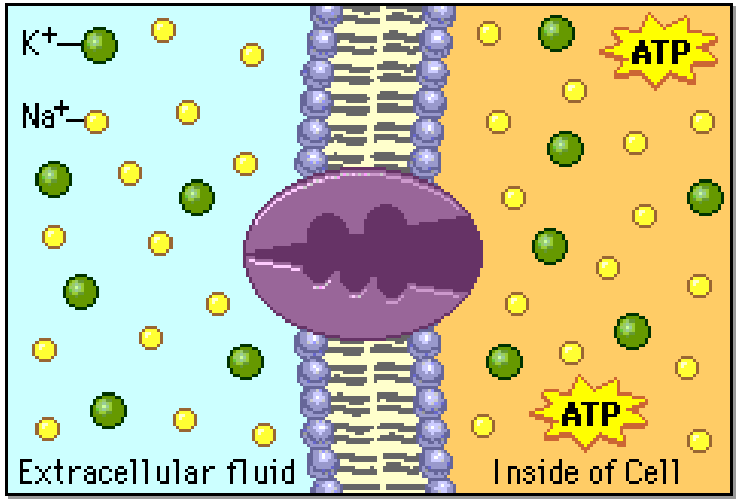
3. Membrane Proteins

Carrier proteins:

- **Highly specific**
- **Conformational change** occurs when it interacts with the ion / molecule



- **Binding sites** that alternately open to one side of the membrane then the other
- Constantly flip between two shapes



→ E.g. sodium-potassium pump
Pumps 2 K^+ in, 3 Na^+ out

3. Membrane Proteins

Roles:

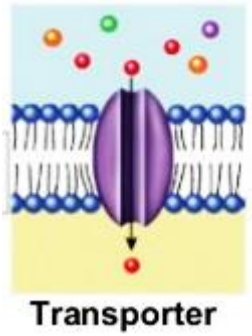
1) **Transport proteins**
   – channel and carrier proteins

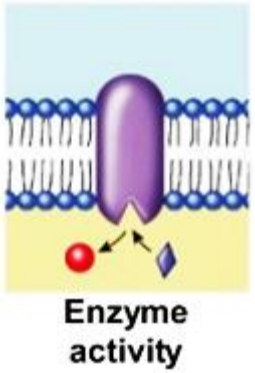
2) **Enzymes**

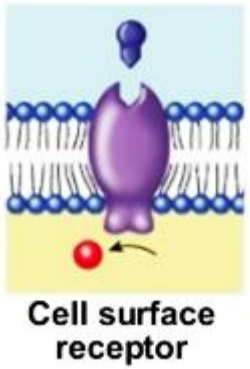
3) **Receptor for cell signalling molecules**

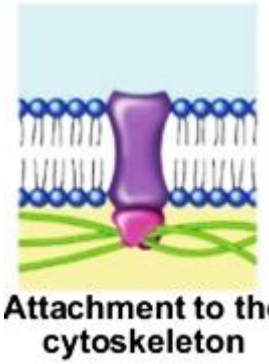
4) **Anchoring cytoskeleton**
   – maintain cell shape

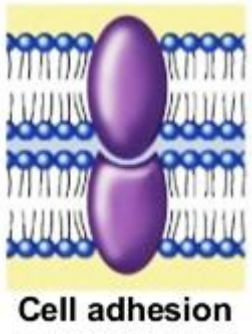
5) **Cell-to-cell adhesion**





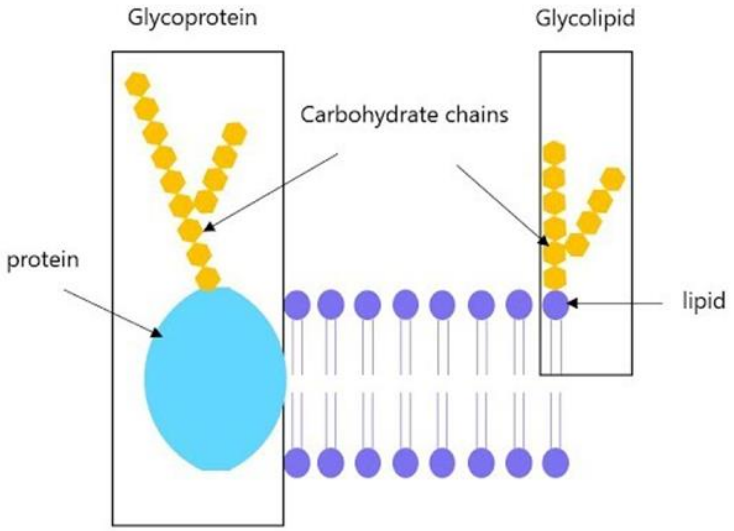






4. Glycolipids

- **Glyco = carbohydrate chain**
- Glycolipid = carbohydrate chains attached to phospholipids
- Glycoprotein = carbohydrate chains attached to protein



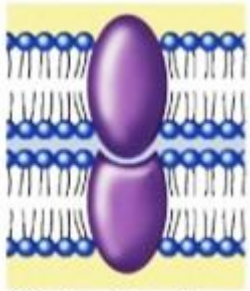
- Carbohydrate chains face outside of cell
- Form a sugary coat on the cell = glycocalyx

4. Glycolipid

Roles:

1) Interacts with water to stabilize membrane structure

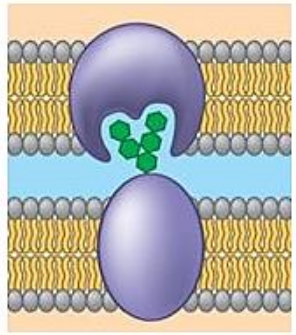
- Able to form **H bonds** with water molecules

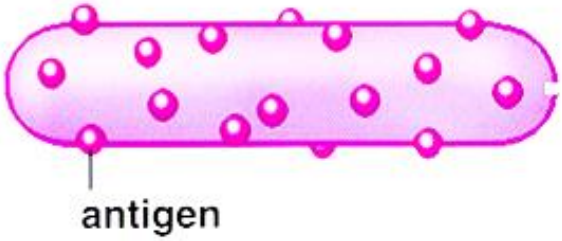


2) Cell-to-cell adhesion

3) Cell recognition

- Acts as cell surface **antigens / markers**
- Macromolecules on cell surface membrane
- **Antigen**: foreign substance that triggers immune response
- To distinguish self from non-self



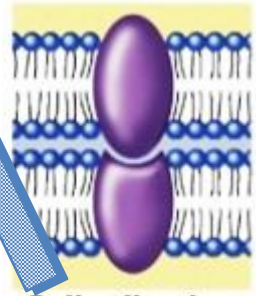


5. Glycoprotein

Roles:

1) Interacts with water to stabilize membrane structure

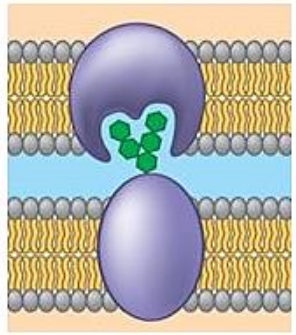
- Able to form **H bonds** with water molecules

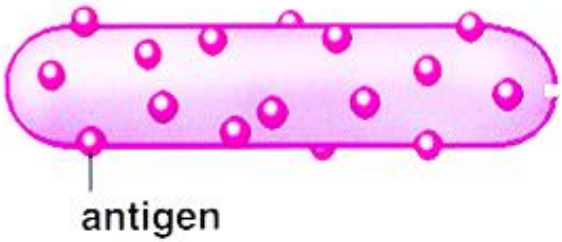


2) Cell-to-cell adhesion

3) Cell recognition

- Acts as cell [illegible] **antigens / markers**
- Macromolecules on cell surface membrane
- **Antigen**: foreign substance that triggers immune response
- To distinguish self from non-self





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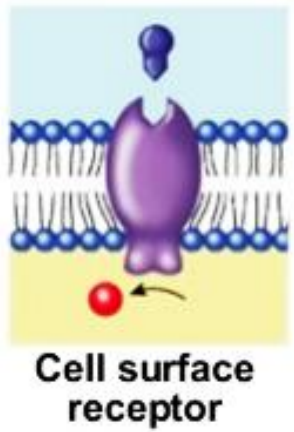
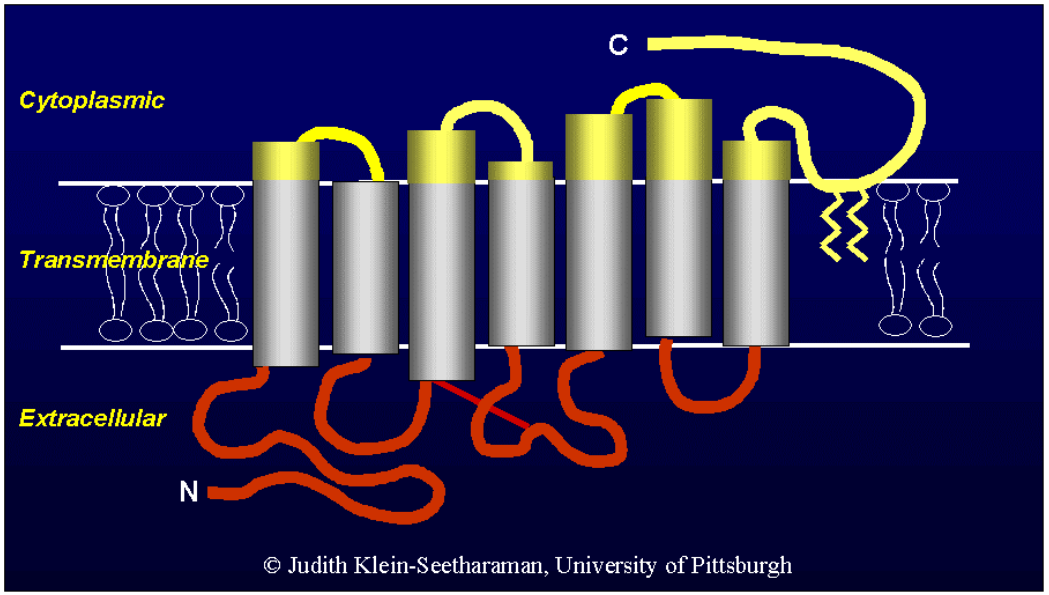
5. Glycoprotein

***Roles*:**

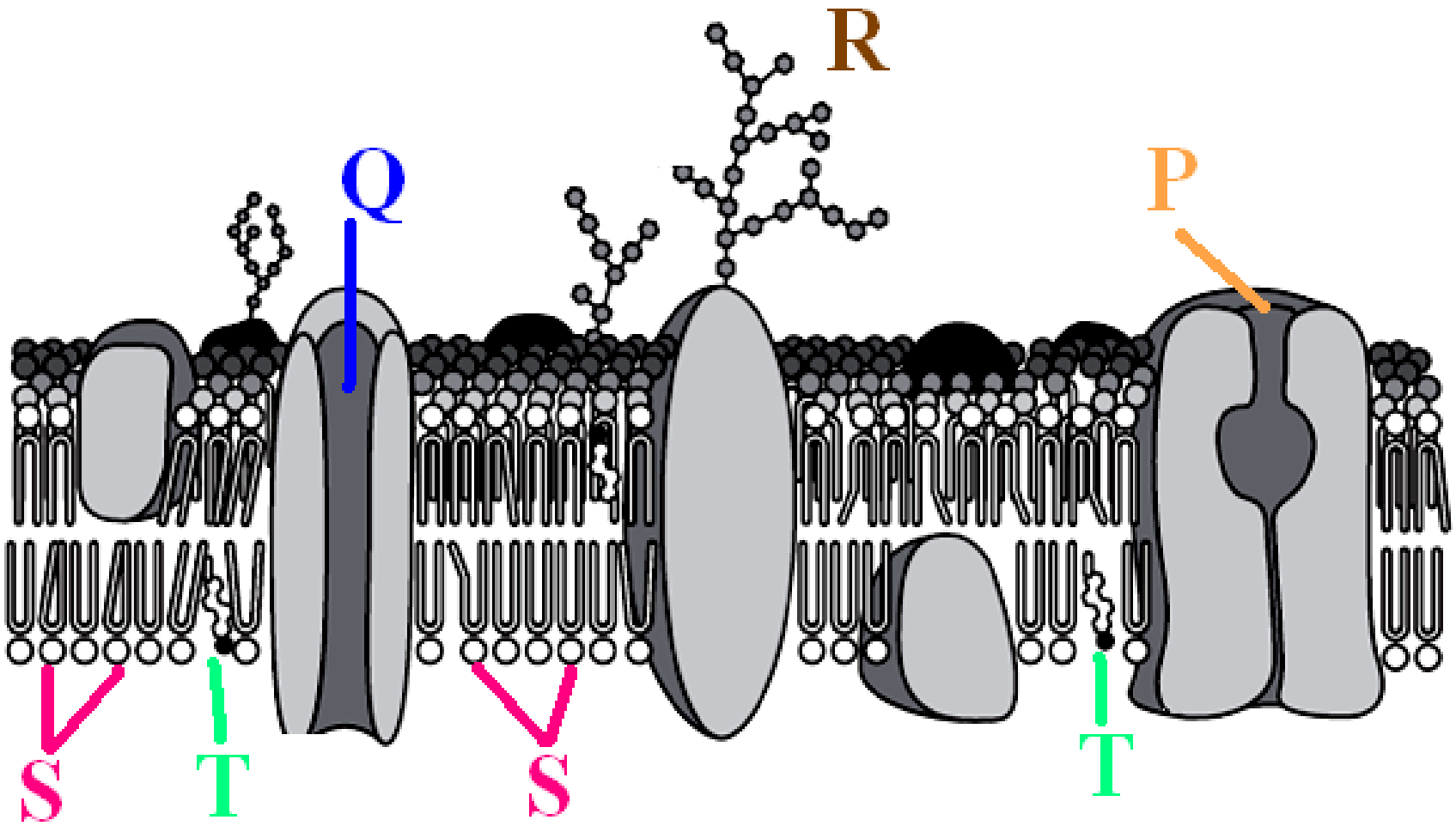
4) Receptor for cell signalling molecules

(for glycoprotein only, not glycolipid)

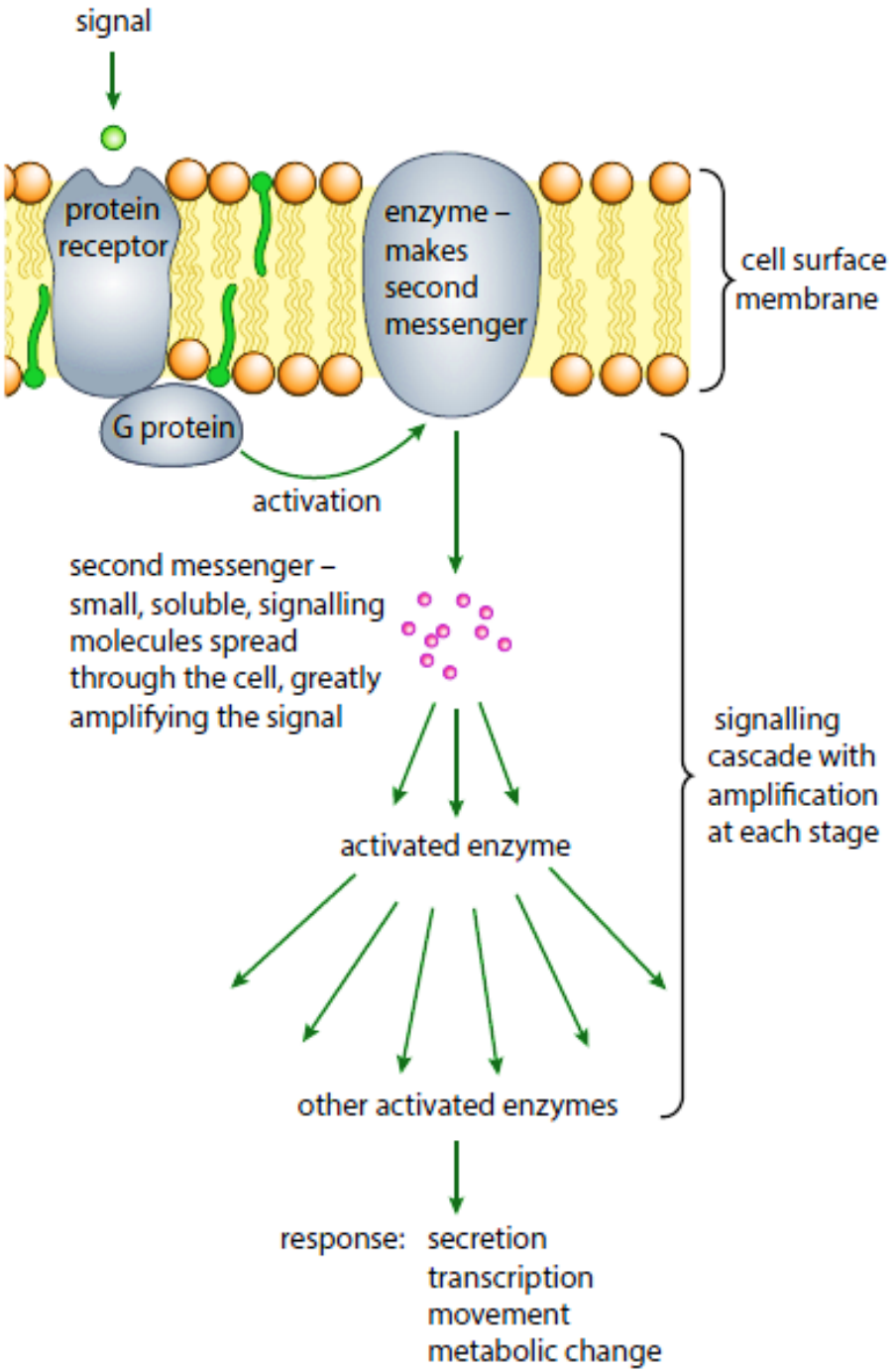




Components of the Plasma Membrane



CELL SIGNALLING

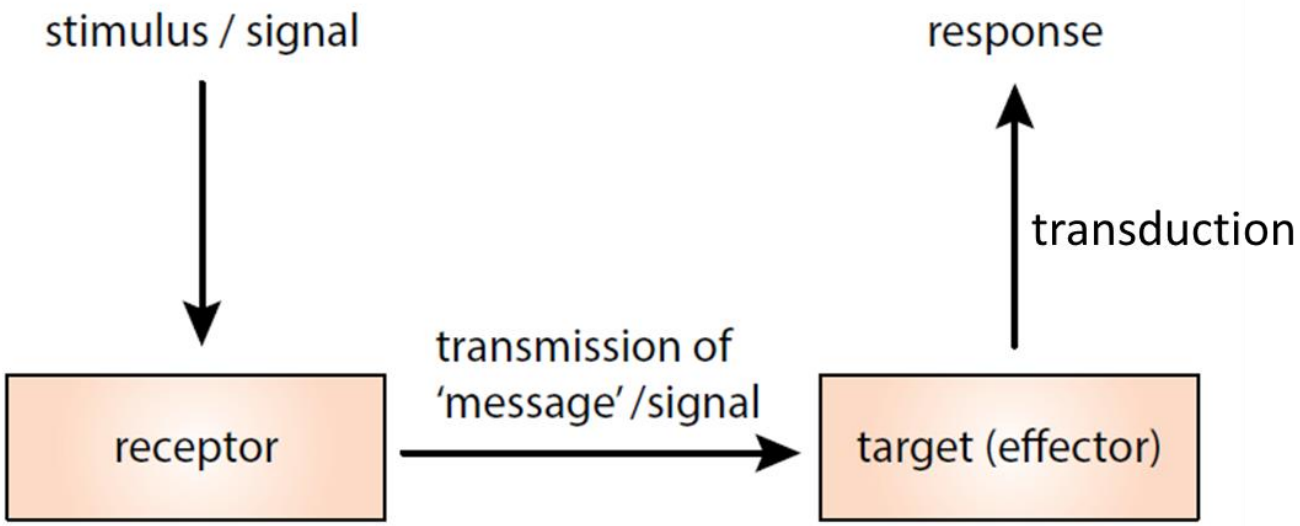


Cell Signalling

- Cell signalling = How cells detect and respond to stimuli
- Also, how cells communicate

→ Involves **ligands** = specific chemicals as signalling molecules

→ Leads to **specific responses**



Cell Signalling

The Process:

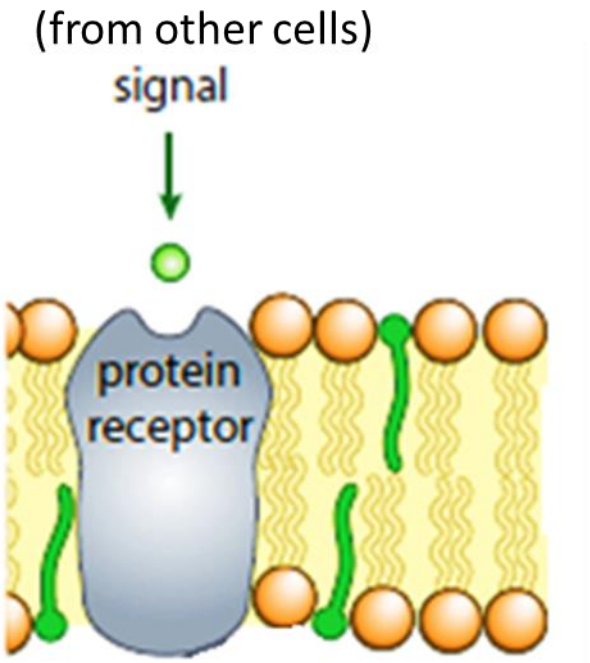
1. **Ligands** secreted from cells
   (E.g. adrenaline from adrenal gland)

2. Ligands transported via **bloodstream**
   to target cells

3. **Ligands bind to cell surface receptors**
   on target cells (E.g. liver / muscle cell)

- Receptor is **specific** and **complementary** in shape to ligand
- **Shape of receptor changes** when ligand binds

→ Signal passed into the cell (transduction)



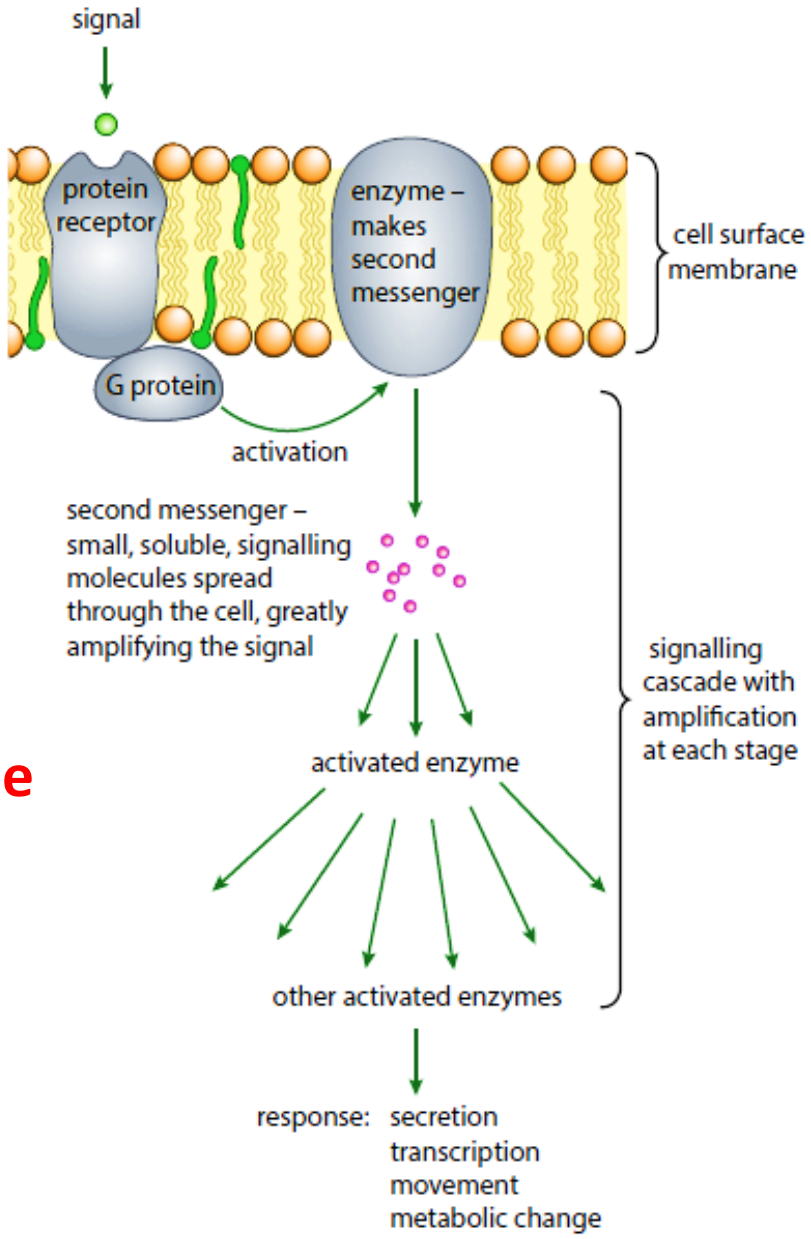
Cell Signalling

4. Receptor activates **G protein**

5. G protein triggers production of many **secondary messengers** by enzyme
   - 2º messengers are **small and soluble**

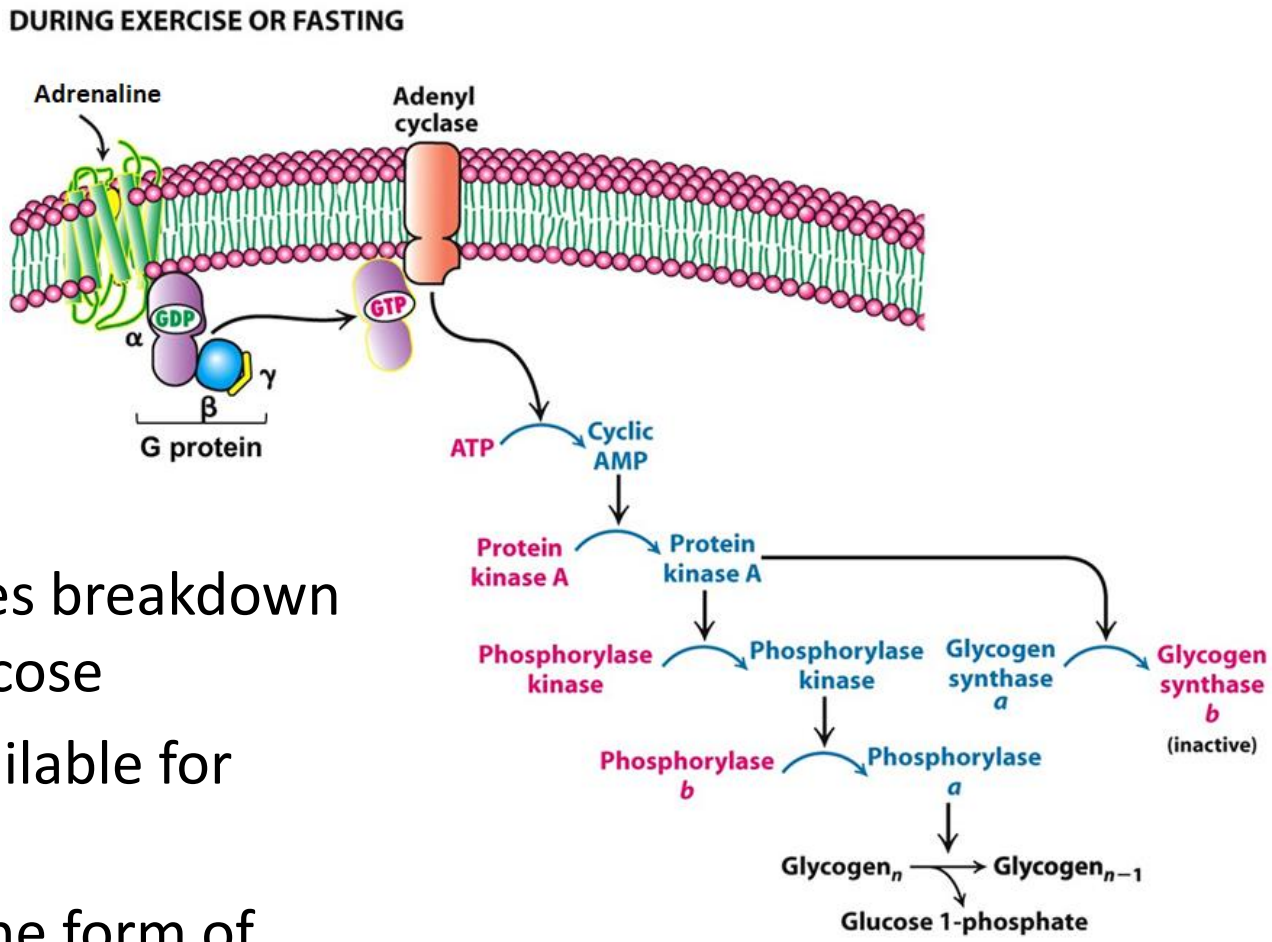
6. 2º messengers triggers **enzyme cascade**
   - Catalysed by enzyme kinases and phosphatases
   - Cause **signal amplification**

7. Enzymes carry out **specific response**



Examples of Specific Responses

E.g. Adrenaline



- Activated enzymes breakdown glycogen into glucose
- More glucose available for respiration
- More energy in the form of ATP produced

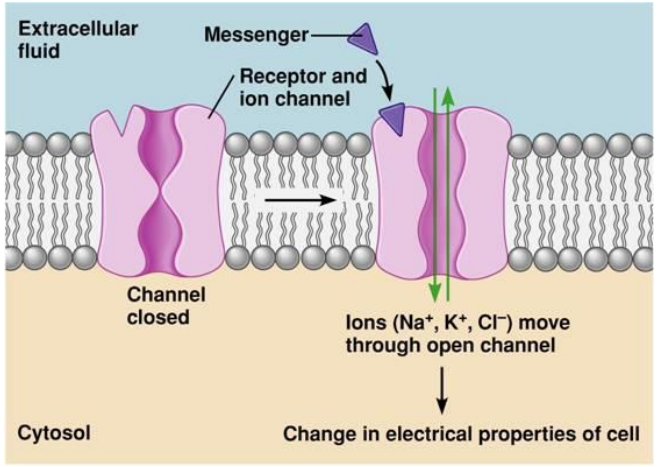
More on this in A2!

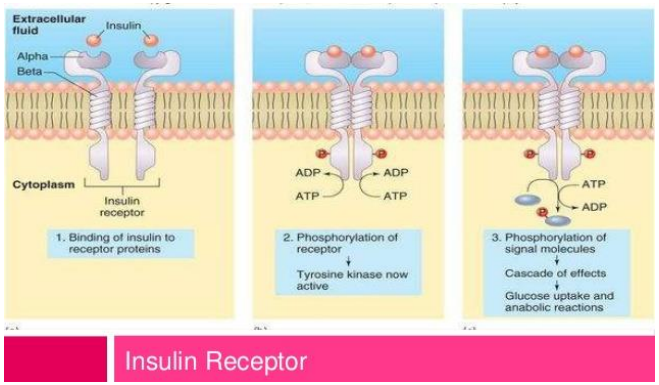
Examples of Specific Responses

Specific response depends on the ligand!

Responses can include:

- Increase transcription of a gene
- Movement
- Change in cell shape
- Secretion
- Activation of an enzyme
- Altered metabolism
- Opening an ion channel
- Using the altered receptor directly as a membrane-bound enzyme

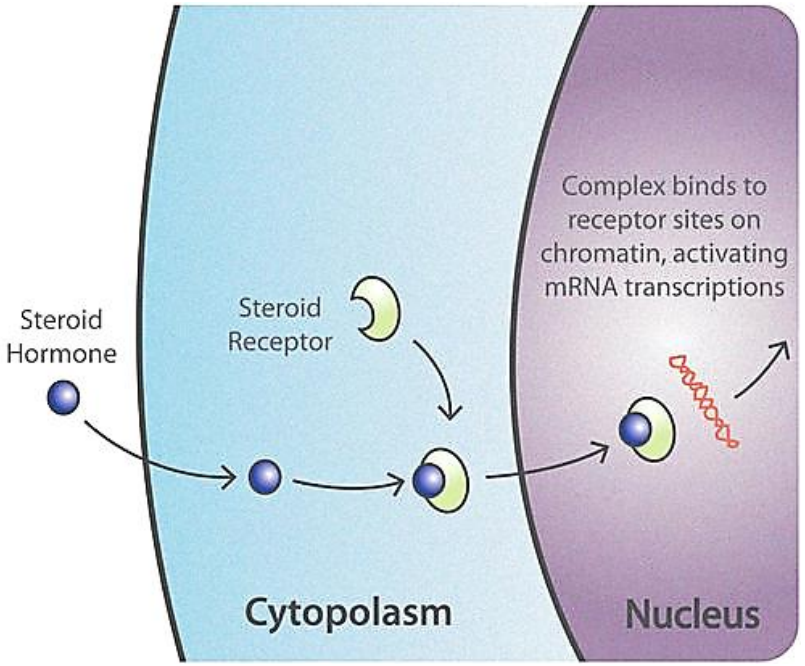




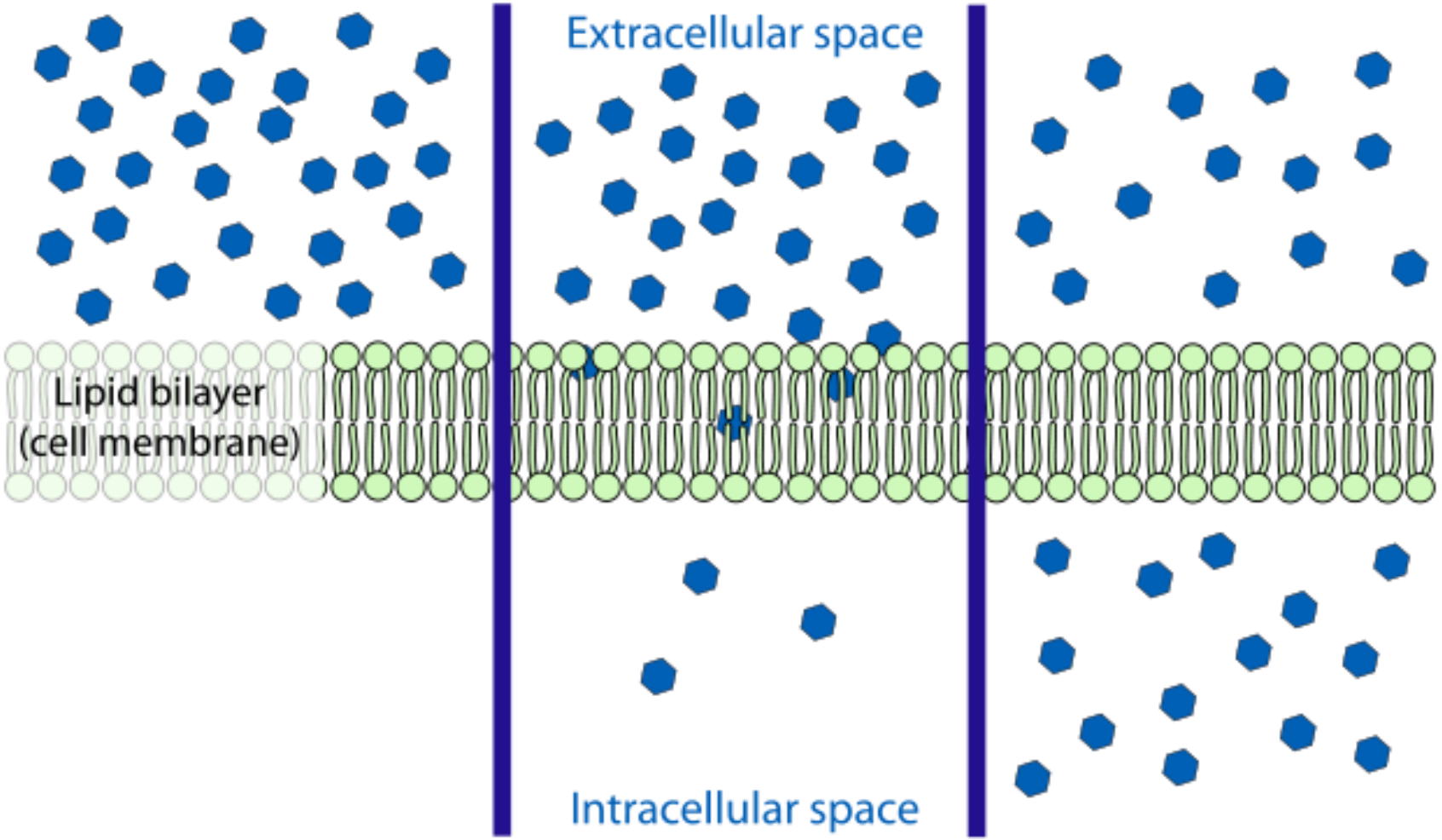
Types of Ligands

1. **Water-soluble** ligands
- Cannot pass through membrane
- Recognised by **receptor** at plasma membrane
- E.g. adrenaline, glucagon

2. **Lipid-soluble** ligands
- Can pass through membrane
- Can **diffuse directly** across the cell surface membrane
- Bind to **intracellular receptors** in the cytoplasm or nucleus
- E.g. steroids, oestrogen



TRANSPORT ACROSS MEMBRANE



Transport Across the Plasma Membrane

5 mechanisms of transport between the cell and its environment:

1. **Simple diffusion**
2. **Facilitated diffusion**
3. **Osmosis**

Passive process
(Does not require energy)

4. **Active transport**
5. **Endocytosis and Exocytosis**

Active process
(Requires energy)

1. Simple Diffusion

Definition:

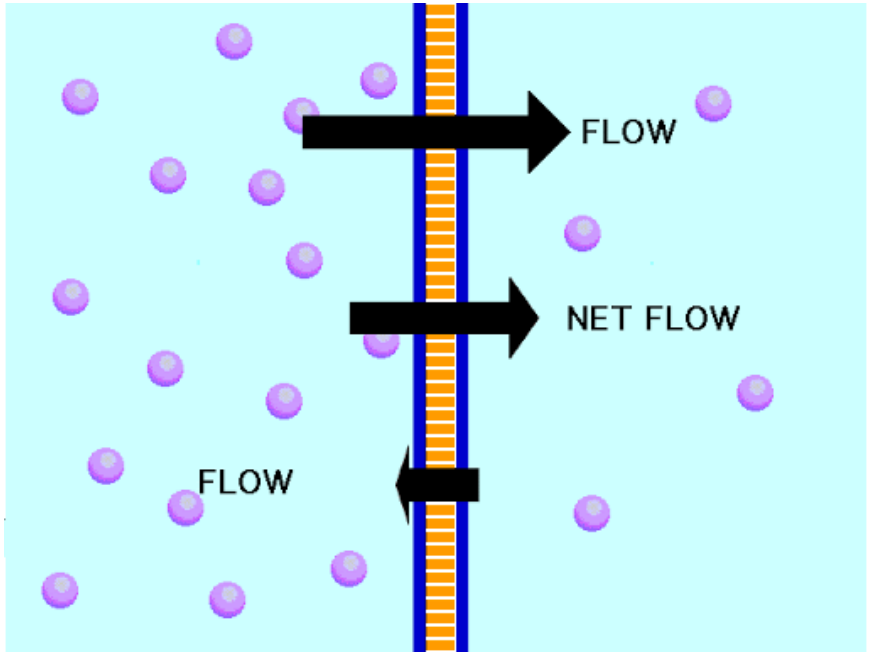
- **Net** movement of molecules
- From a region of high concentration to low concentration
- **Down the concentration gradient**
- Until equilibrium

- In cells, this occurs across a phospholipid bilayer

- **Passive transport**

→ No ATP used

→ Result of random particle movements



1. Simple Diffusion

Substances that can pass through the **phospholipid bilayer** using **simple diffusion** are:

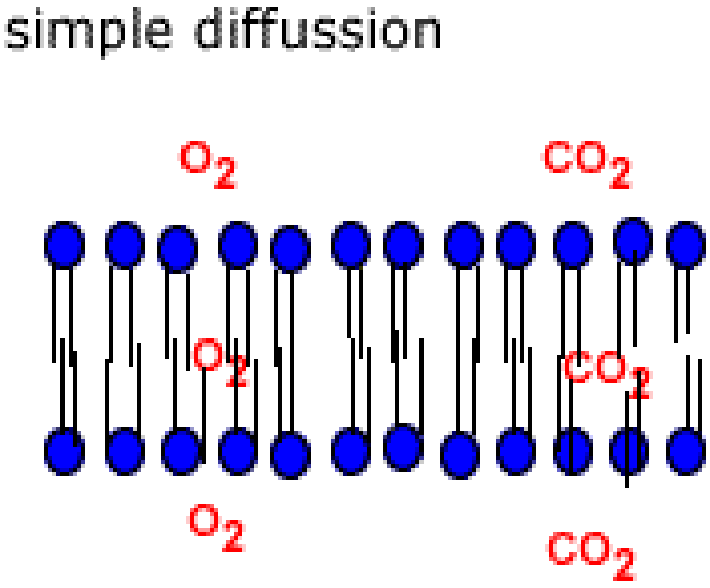
1) Non-polar/ lipid soluble

2)Uncharged

E.g. oxygen and carbon dioxide

3) Small

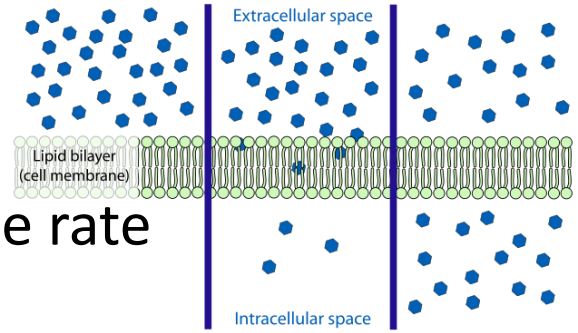
E.g. water molecules (osmosis)



Polar, water soluble, charged molecules are unable to pass through the hydrophobic core of the phospholipid bilayer

Factors Affecting Rate of Simple Diffusion

1) Steepness of the concentration gradient

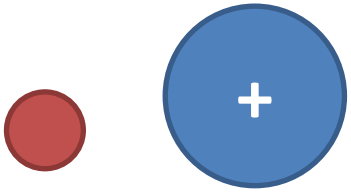


- Greater the difference in concentration, the steeper the conc. gradient, the higher the rate

2) Temperature

- The higher the temperature, the higher the kinetic energy of molecules/ions, the higher rate of diffusion

3) Nature of molecules / ions



- Smaller, non-polar molecules diffuse faster

4) Surface area to volume ratio (SA:V)

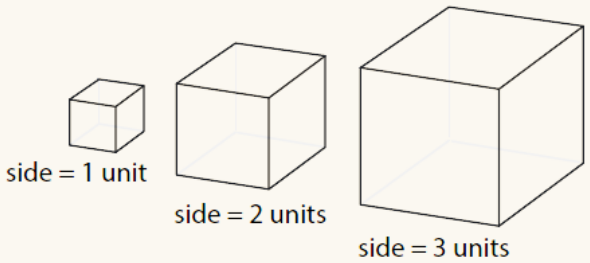
- As the object size decreases, the SA:V increases, the shorter diffusion distance, the higher the rate of diffusion

Surface Area to Volume Ratio (SA:V)

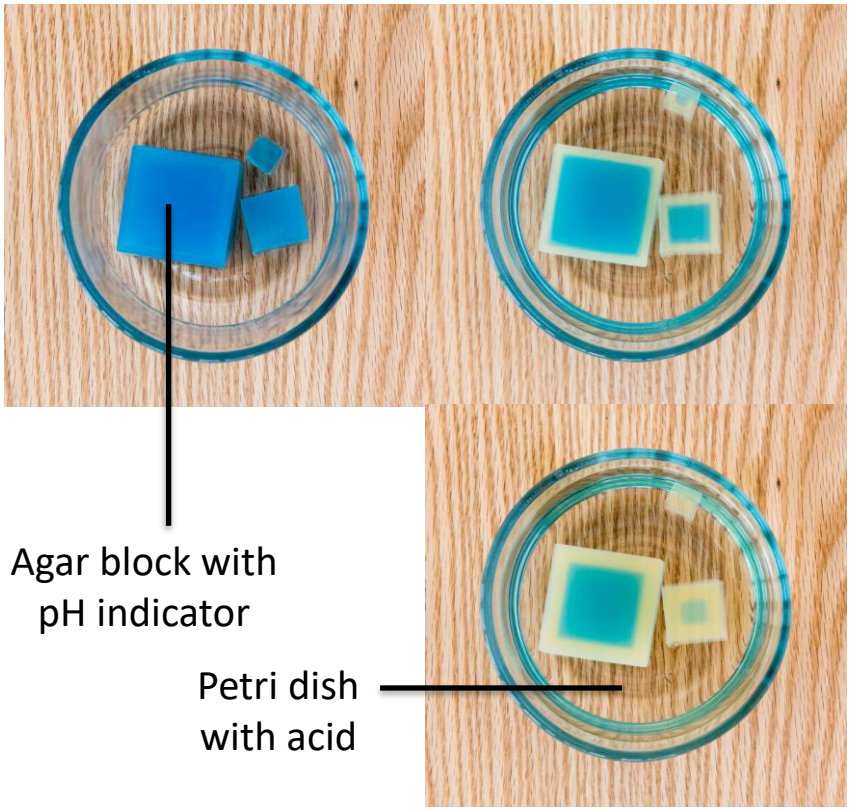
- As the **object size decreases**, the **SA:V increases**, the shorter diffusion distance, the **higher the rate of diffusion**

QUESTION

4.3 The diagram shows three cubes.



Calculate the surface area, volume and surface area : volume ratio of each of the cubes.



2. Facilitated Diffusion

Definition:

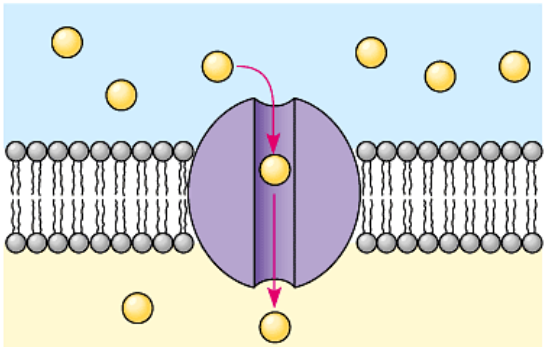
- Diffusion through membrane **transport proteins**
- From a region of high concentration to low conc.
- **Down a concentration gradient**

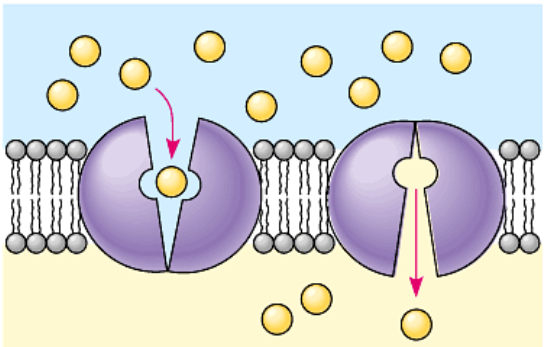
- Involves **channel proteins** and **carrier proteins**

✓ Allow passage of **ions and polar molecules**

- **Passive transport**

→ No ATP required





2. Facilitated Diffusion

Polar, water soluble, charged molecules are unable to pass through the hydrophobic core of the **phospholipid bilayer**

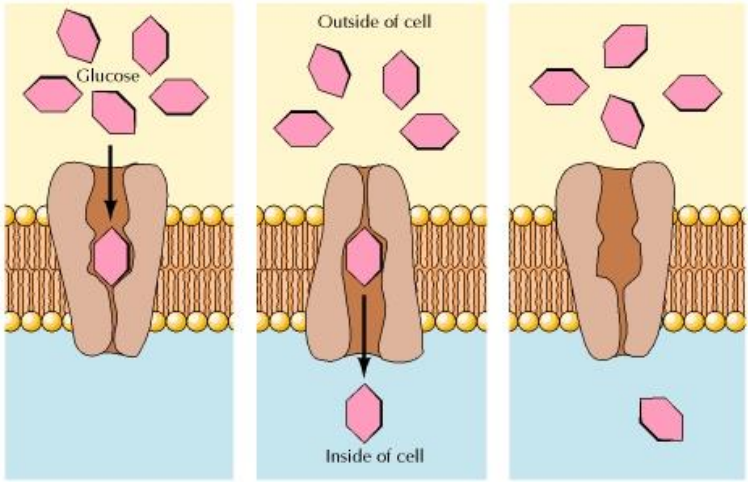
Substances that can pass through using **facilitated diffusion via transport proteins** are:

1) Large or water-soluble molecules

E.g. glucose, amino acids

2) Ions or polar molecules

E.g. Na^+ and Cl^-



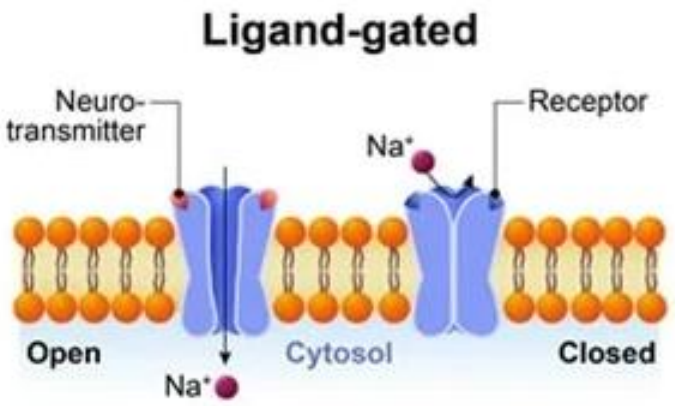
Factors Affecting Rate of Facilitated Diffusion

1) **Steepness of the concentration gradient**

2) **Temperature**

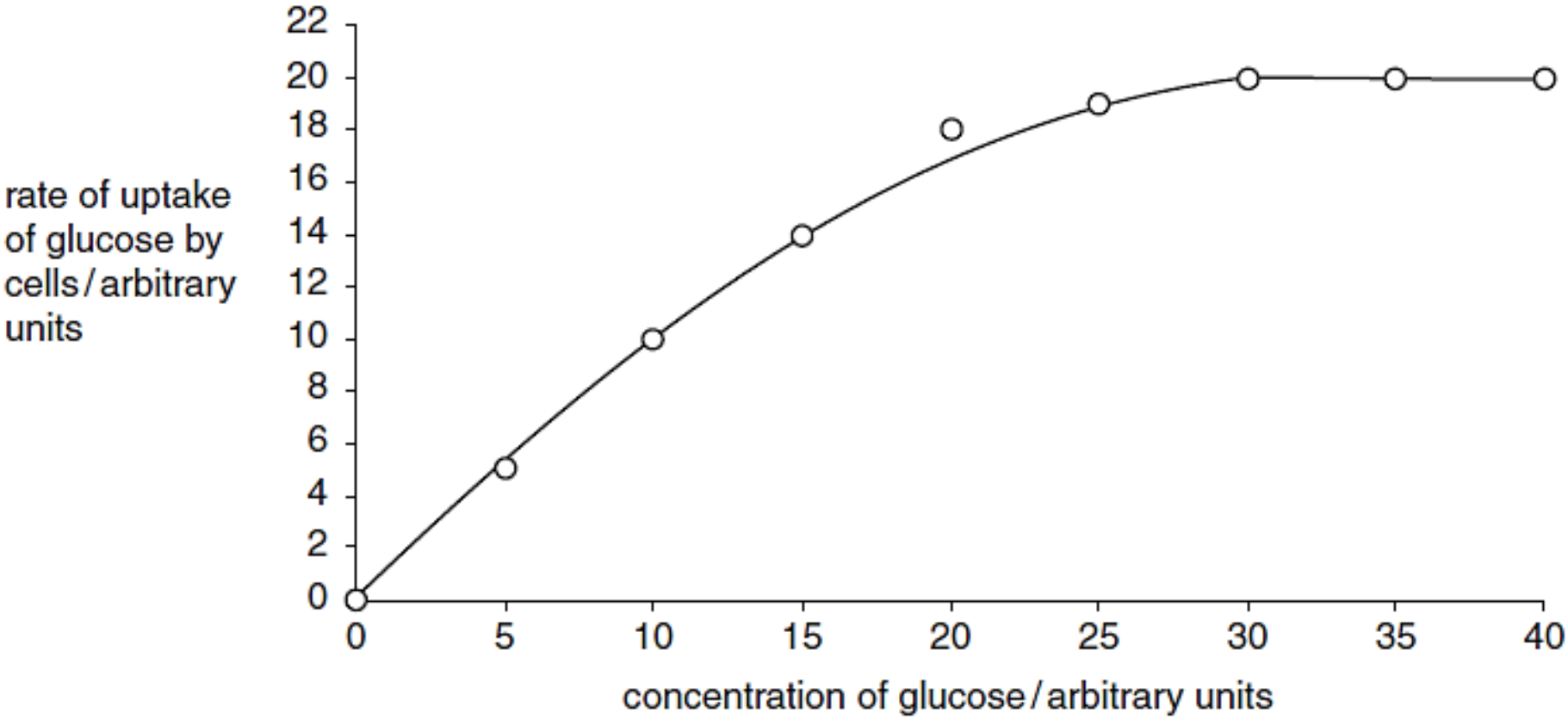
3) **Number of transport proteins available**
   - **Channel proteins: Open or close**

4) **Surface area of the membrane**
   - Large surface area able to fit more transport proteins



Example Question

In an investigation, animal cells were exposed to different concentrations of glucose. The rate of uptake of glucose into the cells across the plasma membrane was determined for each concentration. Figure below shows the results.



Explain how the results of the investigation support the idea that glucose enters cells by facilitated diffusion. [2]

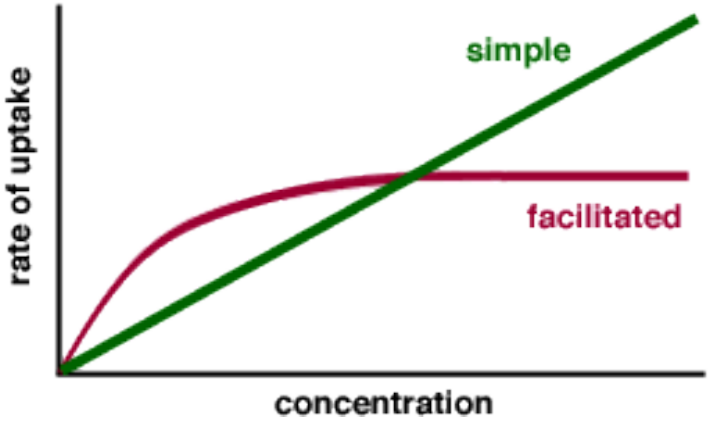
Example Question

It's facilitated diffusion:

- Because the rate of uptake increases with increasing glucose concentration, up to a plateau
- At high concentration, all transport proteins in use

If it is passive diffusion:

- Rate would continue to rise



If it is active transport:

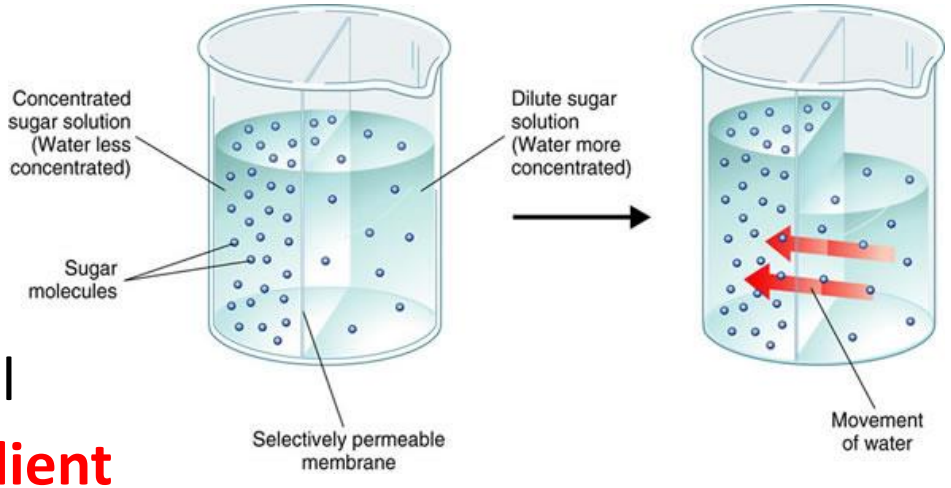
- Rate would be independent of concentration (except at low concentration)

3. Osmosis

*** There is no such thing as water concentration!***

We use the term **water potential (Ψ)**

Ψ = **the tendency of water molecules to move from one area to another**


Concentrated sugar solution (Water less concentrated)
Dilute sugar solution (Water more concentrated)
Sugar molecules
Selectively permeable membrane
Movement of water

Definition:

- Diffusion of **water**
- From a region of high water potential to low water potential
- **Down the water potential gradient**
- Across a **partially permeable membrane**
- Until equilibrium

- **Passive transport**

→ No use of ATP

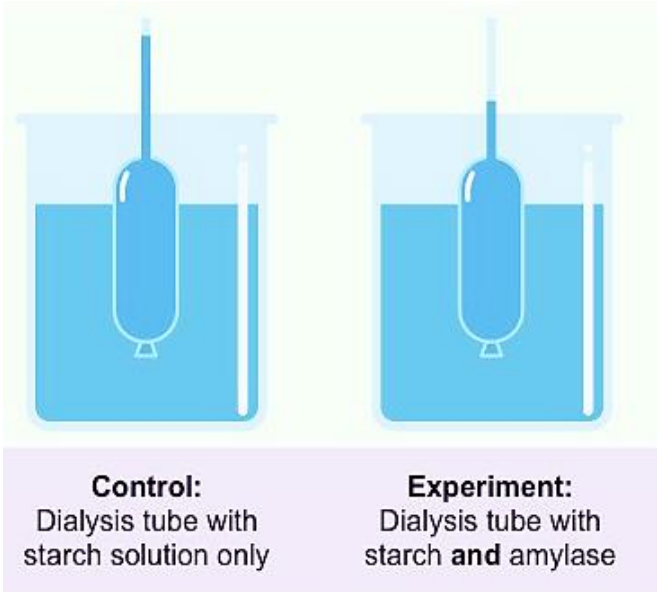
Visking Tube Experiment

- In control, **starch cannot diffuse out**

→ **Water diffuse in by osmosis**

→ Raised water level

→ Solution in beaker remains blue when heated with Benedict's solution



- In experiment, **maltose diffuses out**

→ Less water diffuse in by osmosis

→ Solution in beaker results in **brick-red precipitate** when heated with Benedict's solution

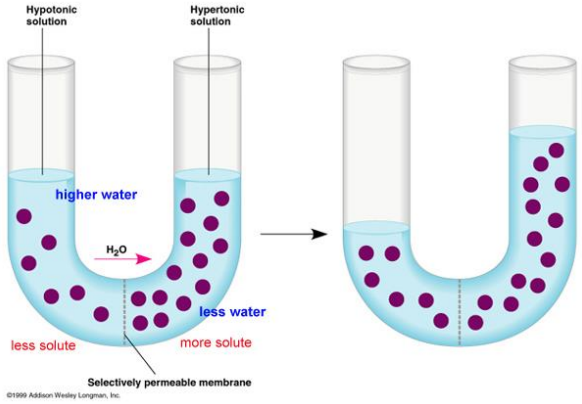
Water Potential, Ψ depends on…

1. How much water there is in relation to solutes

- Concentration of the solution
- More solutes present, water more likely to move in
- **Solute potential, Ψ_s** **-ve value**
- **Ψ_s of pure water = highest = 0**
- **As concentration increases, Ψ_s more negative = Ψ_s decreases**

2. How much pressure is applied to it

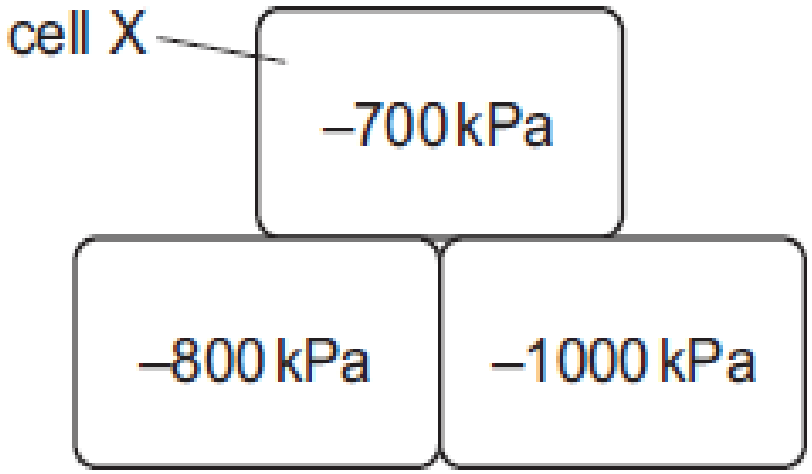
- More pressure, more likely to move out
- **Pressure potential, Ψ_p** **+ve value**
- Esp in **plant cells**, bcs they have **cell wall**



$\Psi = \Psi_s + \Psi_p$ **Overall -ve value**

Example Question

The diagram shows the water potential of three cells.



In which directions will there be net movement of water by osmosis to or from cell X?

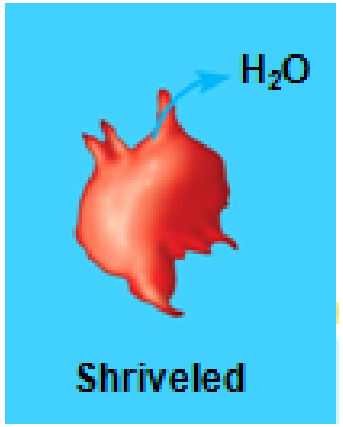
Osmosis in Animal Cells

No cell wall, no pressure potential!

$\Psi = \Psi_s$

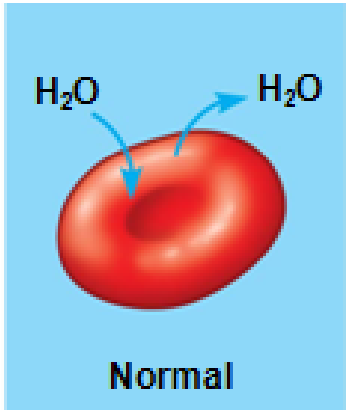
1) When the external solution is hypertonic to the animal cell

- **Higher concentration of solutes outside**
- **Water potential outside is lower (more negative)**
- Water diffuse **out** of cell **by osmosis**
- Cell shrinks



2) When the external solution is isotonic to the animal cell

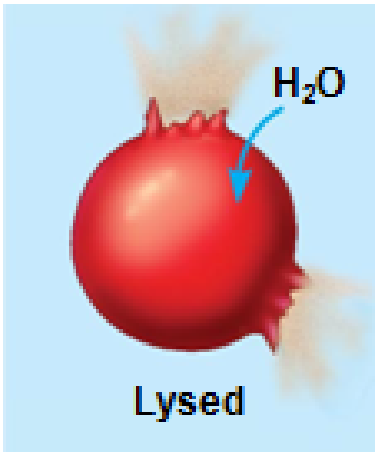
- Water potential outside animal cell similar to cell's content
- **No net gain/loss** of water
- Cell **maintains its shape**

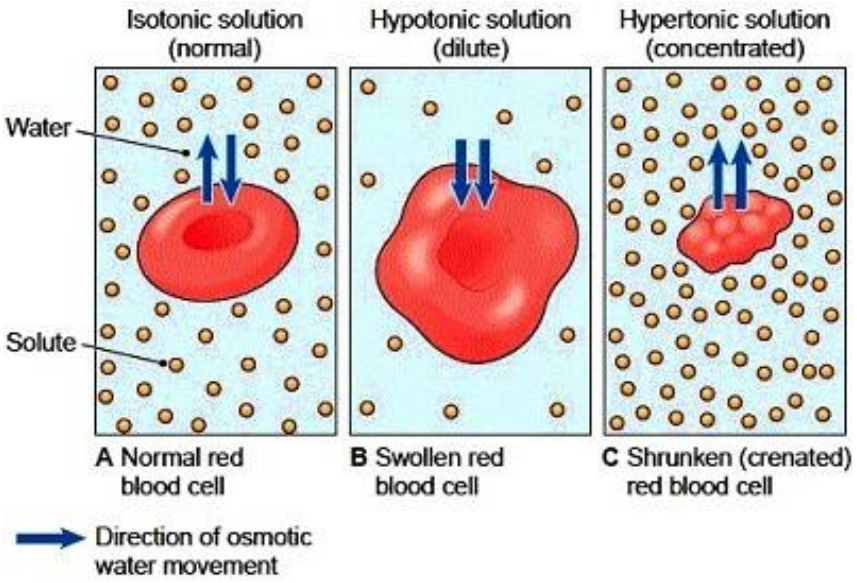


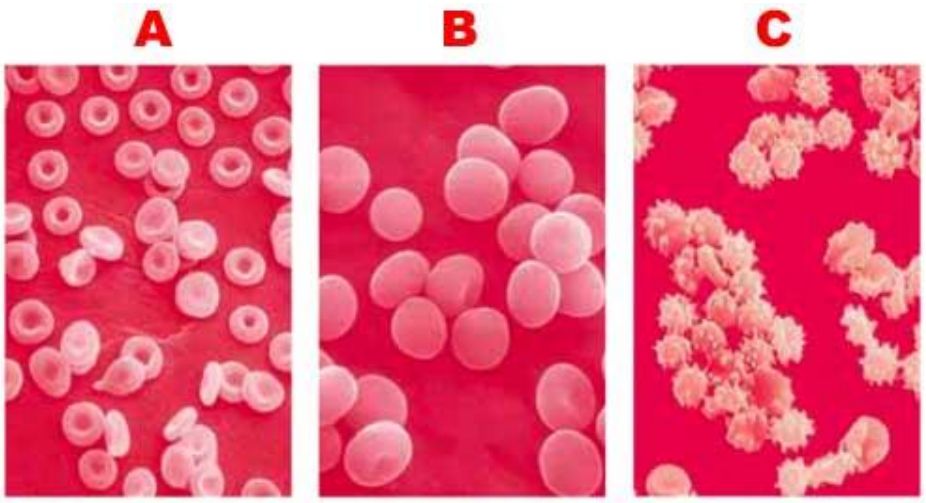
Osmosis in Animal Cells

3) When the external solution is hypotonic to the animal cell

- **Lower solute concentration outside**
- **Water potential outside animal cell higher (less negative)**
- Water diffuse **into** cell **by osmosis**
- Cell volume increases and bursts (**lyse**)







P/S: words like crenation and haemolysis only apply to RBC, not other animal cells

Osmosis in Plant Cells

1) When the external solution is hypertonic to the plant cell

- **Higher conc of solutes outside cells**

→ **Lower / more negative water potential** outside

→ Water **leaves** the plant cells **by osmosis**

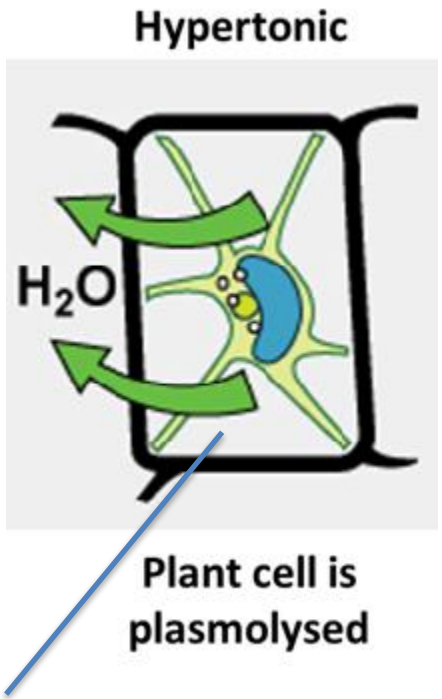
→ Water potential in cells decreases

Result:

- **Protoplast shrinks**, pull away from the cell wall

→ **Plasmolysis** occurs

- No pressure on cell wall, so $\Psi_p = 0$
- Therefore $\Psi = \Psi_s$ only



Osmosis in Plant Cells

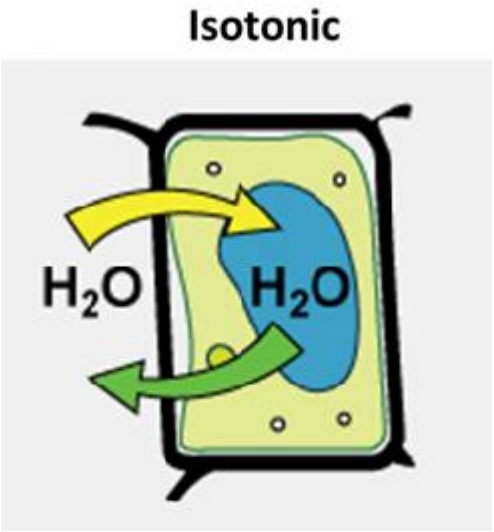
2) When the external solution is isotonic to the plant cell

- Plant cell and solution are in the state of equilibrium
- **No net movement of water**

- **Protoplasm just began to shrink away from cell wall**

→ **Incipient plasmolysis**

- No pressure on cell wall, so $\Psi_p = 0$
- Therefore $\Psi = \Psi_s$ only



Plant cell is in state of incipient plasmolysis

Osmosis in Plant Cells

3) When the external solution is hypotonic to the plant cell

- **Low conc of solutes outside cells**

→ **Higher water potential outside**

→ Water diffuse **into** cells **by osmosis**

→ Water potential in cells increases

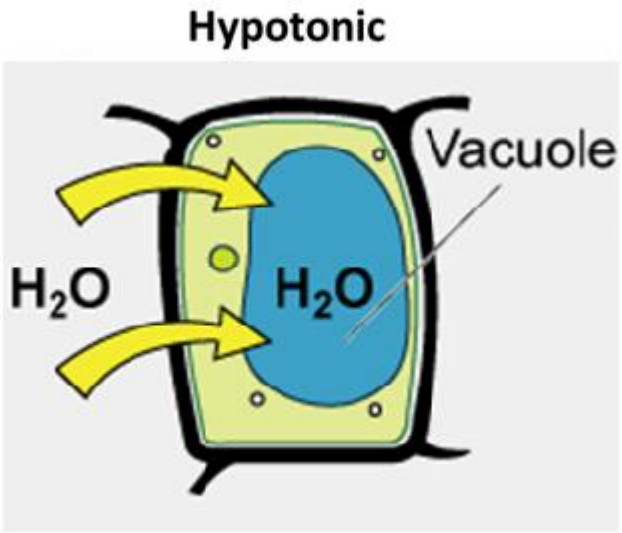
Result:

- **Protoplast pushes against cell wall**

→ The cell becomes **turgid**

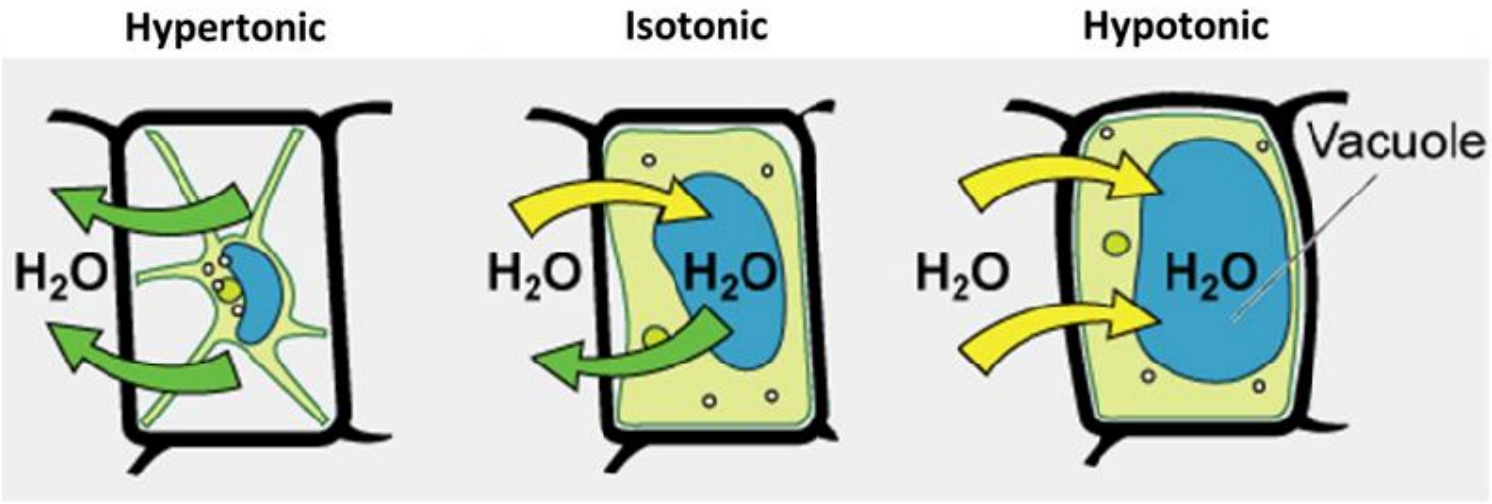
- **Ψ_p** or **turgor pressure** in cells builds up
- Increases water potential of the cell further

- Water potential in cell, **$\Psi = \Psi_s + \Psi_p$**



Plant cell is turgid

Osmosis in Plant Cells



Plant cell is plasmolysed

$\Psi_p = 0$

$\Psi = \Psi_s$

Plant cell is in state of incipient plasmolysis

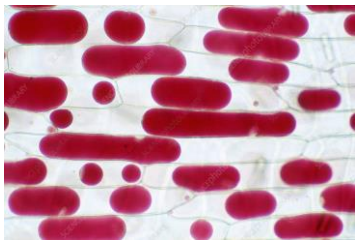
$\Psi_p = 0$

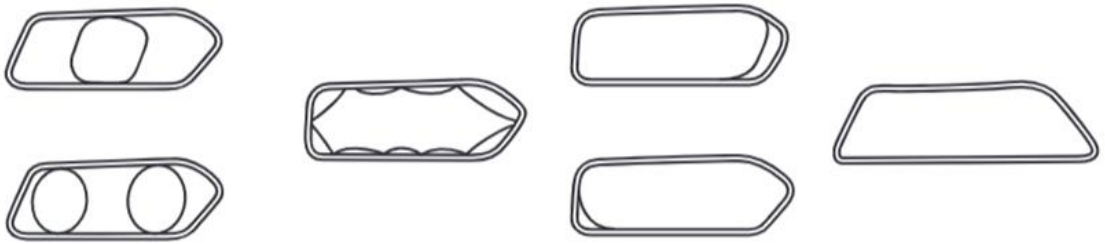
$\Psi = \Psi_s$

Plant cell is turgid

$\Psi = \Psi_s + \Psi_p$

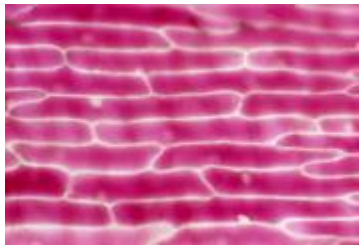
Onion cells





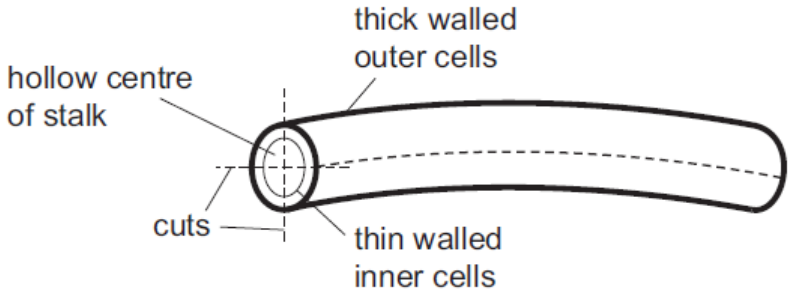
complete plasmolysis | more plasmolysis | slight plasmolysis | no plasmolysis

Onion cells

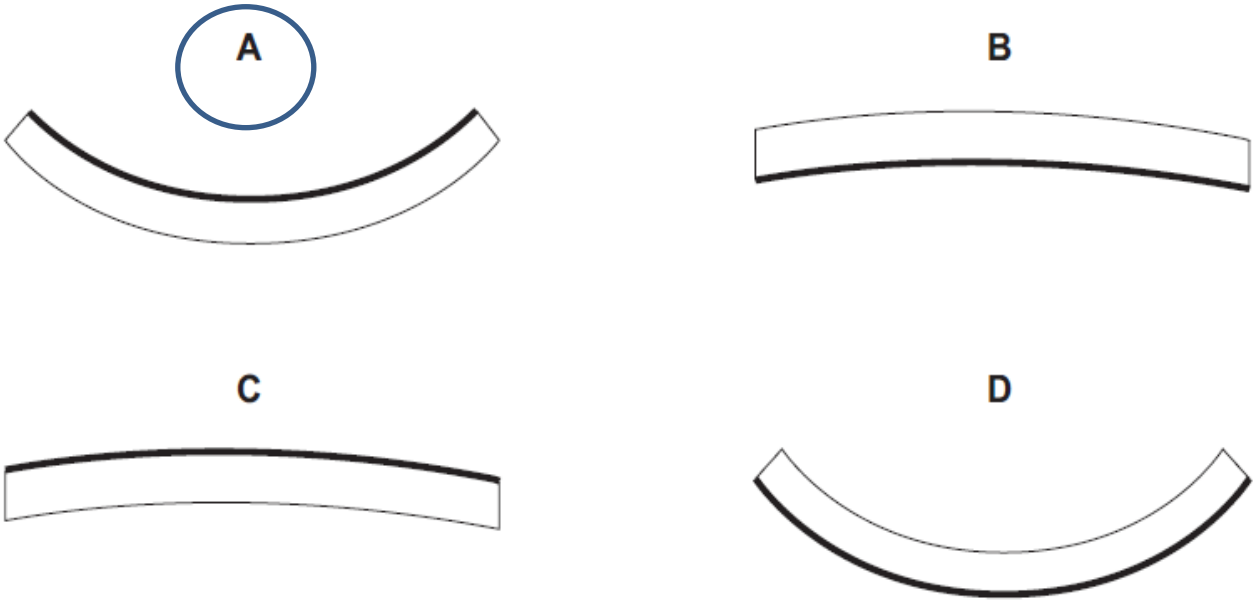


Example Question

The stalk of a dandelion flower is a hollow tube. Pieces of the stalk are cut as shown and placed in sucrose solutions of different water potentials.



Which diagram shows the piece that is placed in the sucrose solution with the highest water potential?



4. Active Transport

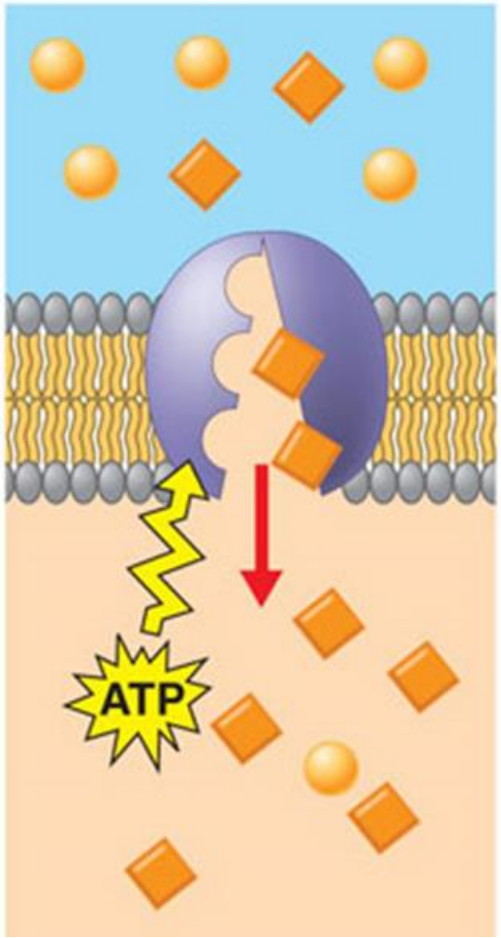
Definition:

- Movement of molecules or ions through **carrier proteins**
- From a region of low concentration to high concentration
- **Against the concentration gradient**

- **Using energy** in the from of ATP

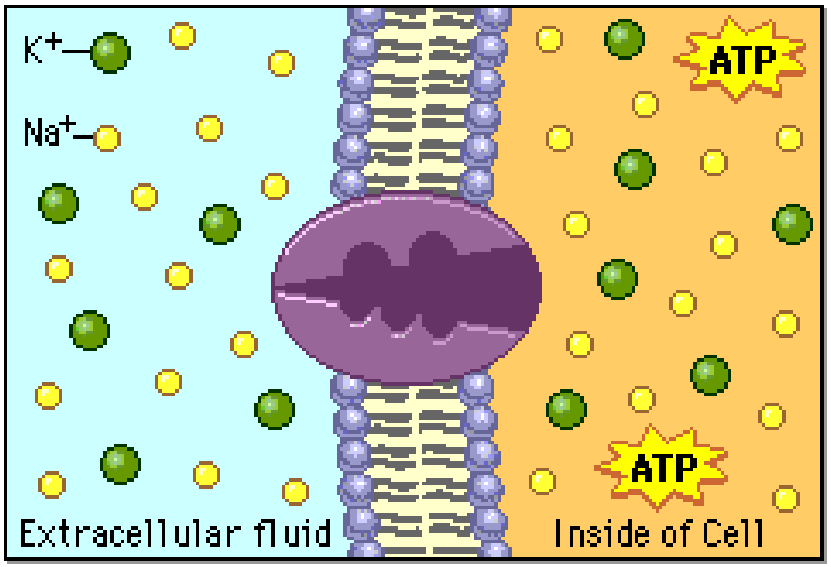
→ Needed for **conformational change** of carrier protein

- Result in cells having a higher concentration of ions compared to the external environment



4. Active Transport

E.g. sodium-potassium pump



- Carrier protein
- Pumps **2 K^+ in, 3 Na^+ out**
- Result: inside of cell becomes less positively charged than outside

- Uses **1 ATP**

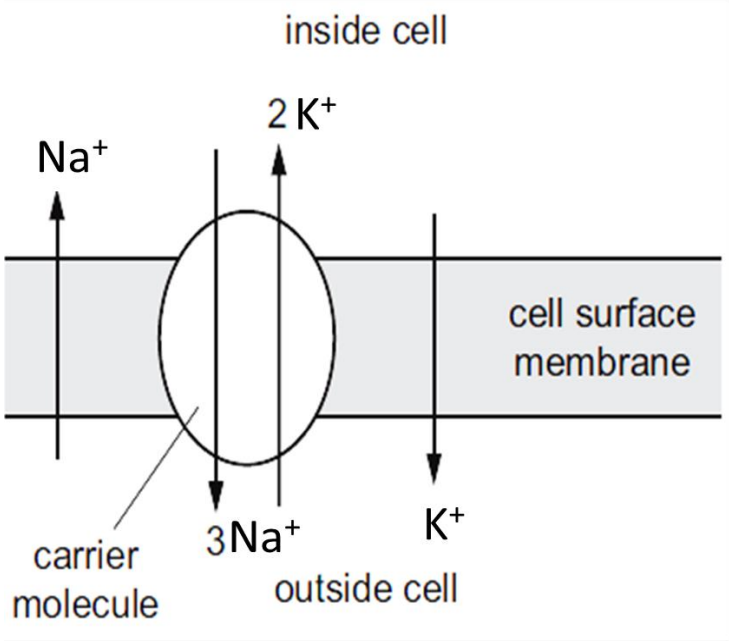
- Carrier protein also acts as enzyme **ATPase**
- Has binding sites for Na^+ and K^+, and an active site for ATP
- **ATP → ADP + Pi + energy**
- Needed for **conformational change** of carrier protein

4. Active Transport

Roles:

- **Sodium-potassium pumps** in cells

→ Important in nerve impulses



- Transport of ions from soil via root hairs

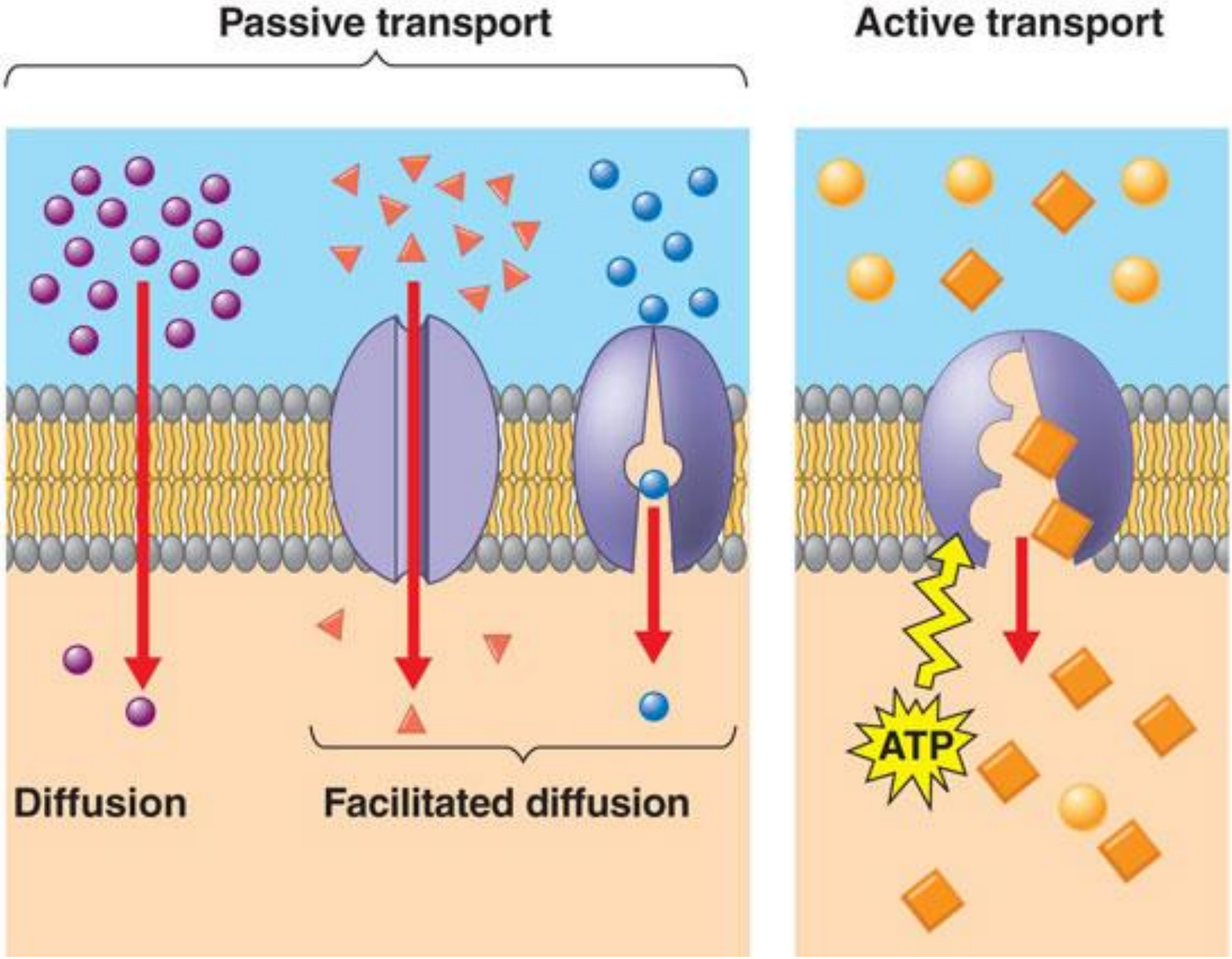
→ Contributes to root pressure

- Hydrogen pumps in cells

→ Translocation of sucrose into phloem

- Absorption in the intestines

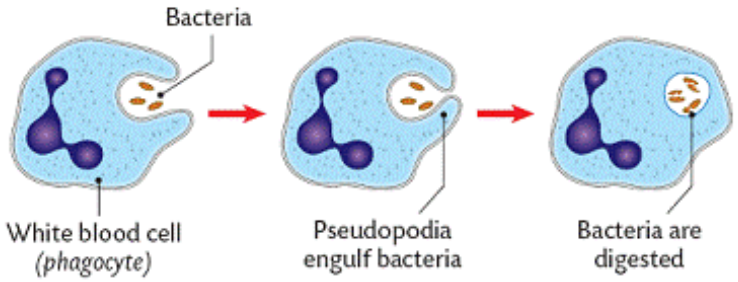
- Reabsorption in the kidneys

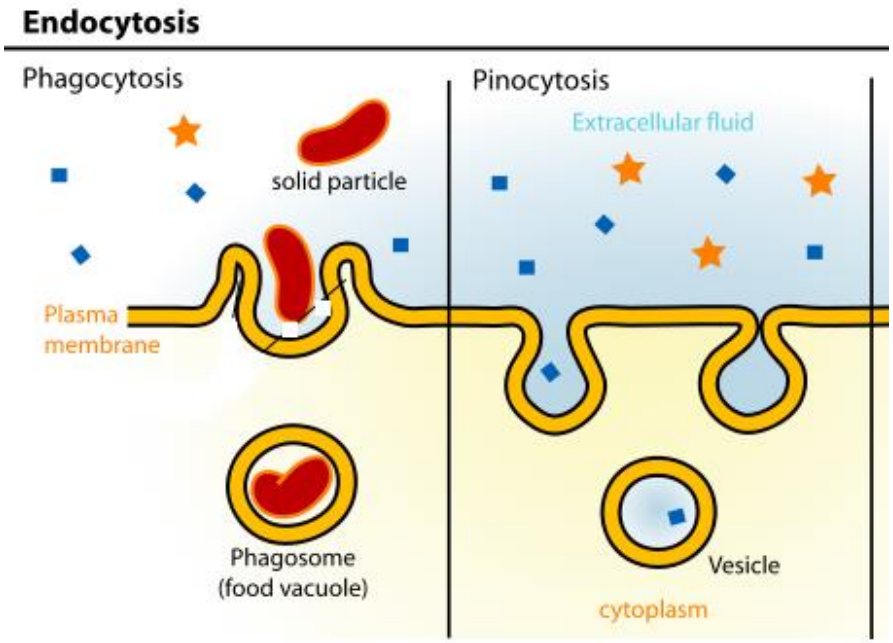

Passive transport
Active transport
Diffusion
Facilitated diffusion
ATP

5. Endocytosis and Exocytosis

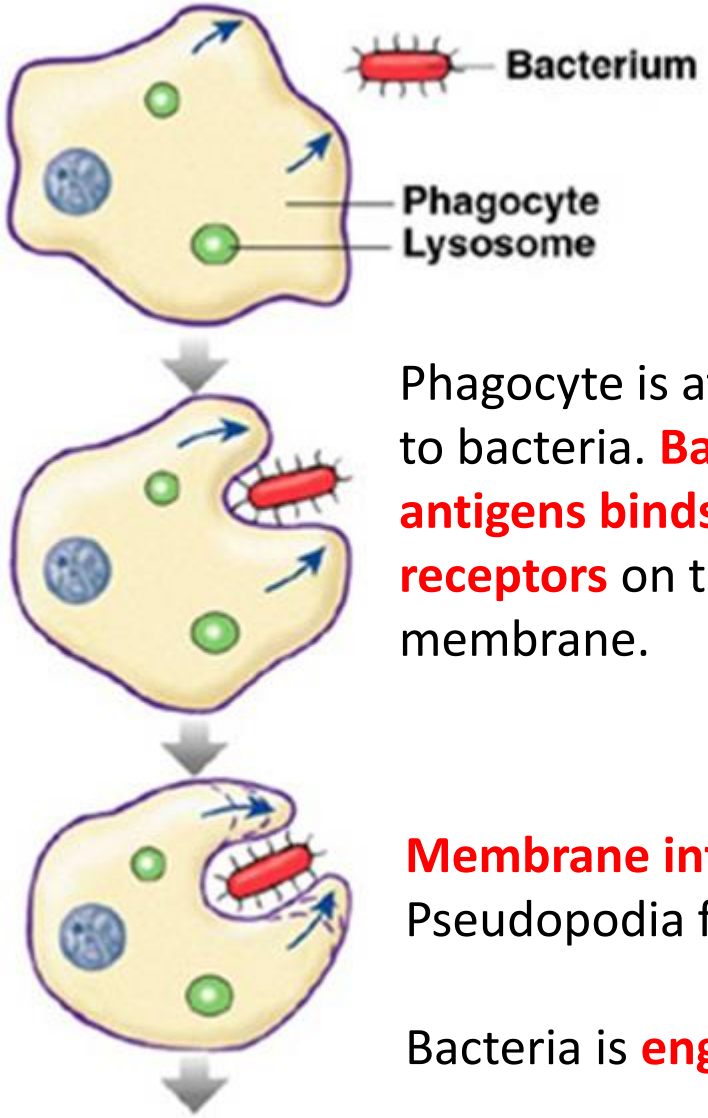
- Mechanism to transport **large quantities** of substances
- **Requires energy** in the form of ATP

- **Endo**cytosis = into cell
  - Phagocytosis = solids
  - Pinocytosis = liquids
- **Exo**cytosis = out of cell





Mechanism of Phagocytosis



Phagocyte is attracted to bacteria. **Bacterial antigens binds to receptors** on the cell membrane.

Membrane infolds. Pseudopodia forms.

Bacteria is **engulfed.**

Membrane fuses to form **endocytic vesicle / phagosome.**

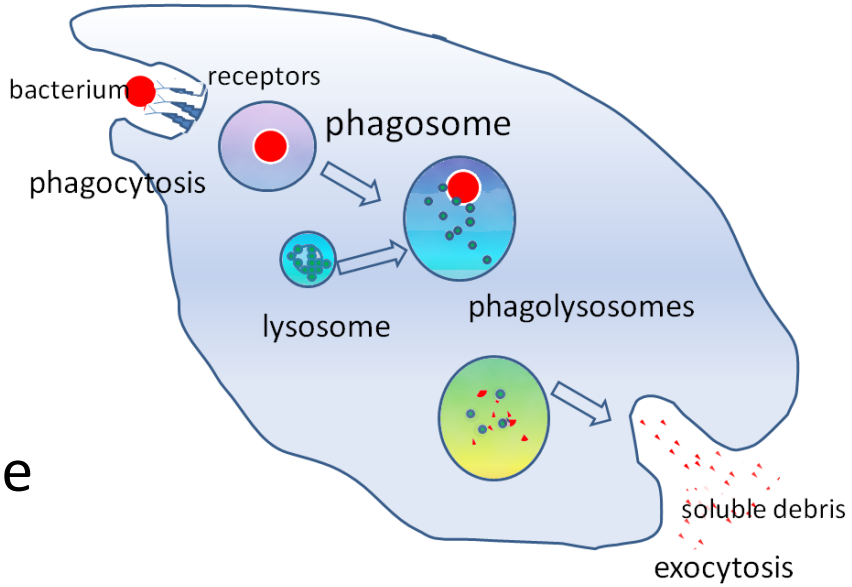
The vesicle **fuses with lysosomes** containing hydrolytic enzymes, that catalyses hydrolysis.

Enzymes break down protein / DNA / lipid peptidoglycan / carb.

The bacterium is killed and digested within the vesicle.

https://www.youtube.com/watch?v=JnlULOjUhSQ
https://www.youtube.com/watch?v=iZYLeIJwe4w

Exocytosis



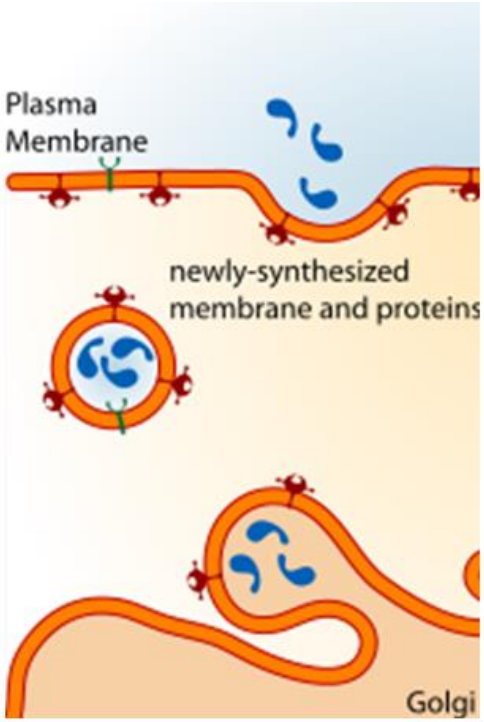
- Substances packaged into **secretory vesicles**

→ **Fuse** with cell surface membrane

→ Release contents

- E.g. Secretion of digestive enzymes and hormones from cells

https://www.youtube.com/watch?v=U9pvm_4-bHg



Chapter Outline

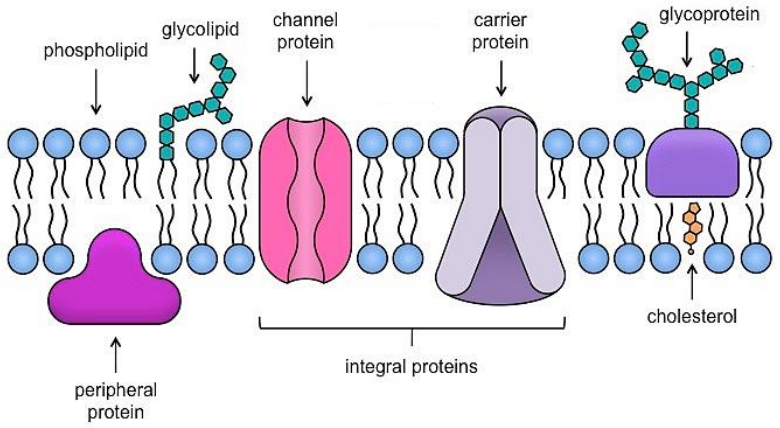
Part 1: Cell Membrane Structure and Function

- Fluid mosaic model
- Roles of:
  - Phospholipids
  - Cholesterol
  - Proteins
  - Glycolipids
  - Glycoprotein

Part 2: Cell signalling

Part 3: Transport Across Membrane

1. Diffusion
2. Facilitated diffusion
3. Osmosis
4. Active transport
5. Endocytosis and exocytosis



Related Videos (for fun)

Basic Components Of Cell Membrane Explained Under 9 Minutes!!!
https://www.youtube.com/watch?v=Aly7AFh46lg

Receptors: Signal Transduction and Phosphorylation Cascade (Prof Dave Explains)
https://www.youtube.com/watch?v=VatdTJka3_M

Cell Membranes and Cell Transport: Molecules like to Move it, Move it
https://www.youtube.com/watch?v=Ptmlvtei8hw

Osmosis and Water Potential (Amoeba Sisters)
https://www.youtube.com/watch?v=L-osEc07vMs

An educational game lol
https://www.biomanbio.com/HTML5GamesandLabs/Cellgames/celldefensehtml5page.html